

**GROUNDWATER SAMPLING AND ANALYSIS PLAN**

**SOLID WASTE LANDFILL FACILITY  
U.S. NAVAL STATION ROOSEVELT ROADS  
CEIBA, PUERTO RICO**

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## 1.0 INTRODUCTION

### 1.1 GENERAL

The existing landfill at U.S. Naval Station Roosevelt Roads has been in operation since the mid-1960s on approximately 85 acres of land in the southeastern area of the base, positioned on a peninsula bounded by Ensenada Honda to the West and Puerca Bay to the South and East. The sanitary landfill operation was initiated using trench fills (below grade) until it reached the original intended capacity in 1990. Currently, the landfill is operated using area fills within the general boundary of the existing landfill area.

The operation of the site was performed by U.S. Navy military and civilian personnel until approximately 1985. From 1985 to present, operation has been provided by private contractors. References indicate that a permit application was originally submitted to the Puerto Rico Environmental Quality Board (EQB) in 1979 for approval. However, the original design of the existing landfill is unknown, and original design documents are not available.

Continued use of the landfill area is urgently needed for present and future operation of the base. In early 1997, a Construction Permit Application, Operating Plan, Groundwater Monitoring System Implementation Plan and Sampling and Analysis Plan, and design drawings for a new municipal solid waste (MSW) landfill cell on the existing site were submitted to EQB. A construction permit for the new MSW landfill cell has been issued by EQB, and development of the new cell is underway.

### 1.2 PURPOSE

This purpose of this document is to revise and update the 1997 Sampling and Analysis Plan (SAP). This document is written by Burns & McDonnell Waste Consultants, Inc. (BMWCD) for semiannual groundwater sampling rounds at the U.S. Naval Station Roosevelt Roads Sanitary Landfill. The SAP includes an overview of the field activities and procedures for groundwater sampling, monitoring well redevelopment, statistical analysis of the data and reporting.

## **1.3 REGULATORY PROGRAM OUTLINE**

### **1.3.1 Federal Program**

On October 9, 1991, the Environmental Protection Agency (EPA) promulgated standards for new and existing municipal solid waste landfills (MSWLFs) under RCRA Subtitle D. The new rule established minimum national criteria for the location, design, operation, cleanup, and closure of MSWLFs under 40 CFR Part 258. States and territories that obtain authorization for individual programs are allowed to exercise flexibility in implementing the new criteria. Owners/operators located in states and territories without approved programs must strictly comply with the federal requirements.

### **1.3.2 Puerto Rico Program**

The Non-Hazardous Solid Waste Regulations (NHSWR) published by the EQB comply with 40 CFR Part 258. Groundwater monitoring programs at MSW facilities are governed by Chapter VII of these regulations.

The NHSWR for groundwater monitoring at sanitary landfills in Puerto Rico set forth requirements and methods of satisfactory compliance to ensure that the design, construction, and operation of sanitary landfills will protect the public health, prevent nuisances, and meet applicable environmental standards. The requirement subsections contained in each section of the regulations delineate minimum levels of performance required of any sanitary landfill operation. The satisfactory compliance subsections are presented as the authorized methods by which the objectives of the requirement can be met. Other techniques for meeting the requirement of the rule can be used with written approval from the EQB. Part of the groundwater monitoring requirements listed in the satisfactory compliance subsections may be waived or altered if the owner/operator can demonstrate that a potential does not exist for migration of fluids generated by the sanitary landfill to the underlying groundwater.

The requirement subsection for groundwater monitoring states "a groundwater monitoring system shall be installed . . . to yield groundwater samples from the uppermost aquifer that represent(s) the quality of background groundwater that has not been affected by leakage from a unit and represent(s) the quality of groundwater passing the point of compliance" (VII: Rule 554.1.A.). EQB requires that analytical methods which accurately measure hazardous constituents and other groundwater quality parameters be used (IV-C: Rule 556.1).

The NHSWR requires that the monitoring wells be capable of monitoring the uppermost aquifer. Groundwater samples shall be analyzed semiannually for Appendix I parameters, which are found in Appendix A.

Existing sanitary landfills must be in compliance with the EQB NHSWR according to the following schedule:

- By October 9, 1994, if located less than 1 mile from a drinking water intake (surface or subsurface)
- By October 9, 1995, if located between 1 and 2 miles from a drinking water intake (surface or subsurface)
- By October 9, 1996, if located more than 2 miles from a drinking water intake (surface or subsurface)

The regulations require the groundwater monitoring system to be capable of yielding groundwater samples for analysis. Upgradient groundwater samples should be representative of background water quality not affected by the sanitary landfill. Downgradient groundwater samples should be capable of detecting significant amounts of fluids generated by the landfill that migrate to the groundwater. The design and installation of the groundwater monitoring system must be certified by a qualified groundwater scientist and must be approved by the EQB. The operation of that groundwater system may not begin without an SAP certified by a licensed chemist authorized to exercise the profession in Puerto Rico. The SAP must also be approved by the EQB.

The owner/operator must first submit a Groundwater Monitoring System Implementation Plan (GWMSIP) to the EQB for approval. The plan must include procedures and techniques for the following activities:

- Design of the groundwater monitoring system
- Activities to be completed in order to build the system
- Activities to be performed for operating the system
- A specific activity schedule, including the date when the system will be ready for startup.

The owner/operator must also submit an SAP to the EQB for approval. The program must include procedures and techniques for the following activities:

- Sample collection
- Sample preservation and shipment
- Analytical procedures
- Chain-of-custody control
- Quality assurance and quality control (QA/QC)

The sampling and analytical methods must be appropriate for groundwater sampling and accurately measure hazardous constituents and the monitoring parameters. The analysis must be performed on unfiltered samples.

The following sections describe the requirements for the initial background sampling, subsequent sampling events, assessment monitoring, and corrective action, if necessary.

#### **1.3.2.1 Initial Sampling**

In accordance with the requirements of Rule 557, an initial sampling must be conducted in which groundwater is collected from all wells in the monitoring well network to establish the background groundwater quality. It should be noted that the site is located at an existing landfill. The current landfill is a Solid Waste Management Unit (SWMU) undergoing corrective action following Resource Conservation and Recovery Act (RCRA) standards. The initial sampling consists of the collection of a minimum of four independent samples from each monitoring well. The samples must be collected following the field, laboratory, and QA/QC procedures described in the SAP, and analyzed for Appendix I groundwater monitoring parameters

### **1.3.2.2 Subsequent Sampling Events**

After the initial sampling for background is completed, groundwater samples must be collected from each well (upgradient and downgradient) on a semiannual basis. The samples again must be collected following the field, laboratory, and QA/QC procedures described in Section I of the SAP and analyzed for the Appendix I parameters. The EQB may specify an alternative frequency for repeated sampling and analysis during the active life of a landfill and the post-closure care period.

The results of the sampling must be analyzed by following the statistical procedures described in the SAP. If the owner or operator determines that there is a statistically significant increase over background for one or more of the Appendix I parameters at any monitoring well at the relevant point of compliance, the owner or operator must place a notice to this effect in the operating record and forward a copy of this notice to the EQB. Within 90 days, the owner or operator must demonstrate to the EQB that a source other than the landfill caused the contamination or that the increase resulted from an error in sampling, analysis, statistical evaluation, or natural variation. If the owner or operator cannot make this demonstration to the EQB, the owner or operator must submit a plan for a groundwater assessment monitoring program to the EQB.

### **1.3.2.3 Assessment Monitoring**

Within 90 days of beginning an assessment monitoring program, and annually thereafter, a sample must be collected from each downgradient well and analyzed for Appendix II groundwater monitoring parameters, which are found in Appendix A. For any new constituents detected during assessment monitoring (not detected during detection monitoring) in the downgradient wells, a minimum of four independent samples from each well (upgradient and downgradient) must be collected and analyzed to establish background concentrations for the new constituents. Within 90 days of the Appendix II background sampling just described, and semiannually thereafter, the owner/operator must sample and analyze for the Appendix I parameters and for those Appendix II parameters detected during the background assessment sampling. The resulting concentrations must be placed in the operating record. The samples must be collected and analyzed in accordance with procedures described in the SAP.

Groundwater protection standards must be established for any Appendix II parameters that were detected, using the following the guidelines:

- For constituents for which a maximum contaminant level (MCL) has been promulgated under Section 1412 of the Safe Drinking Act under 40 CFR Part 141, the MCL for that constituent.
- For constituents for which MCLs have not been promulgated, the background concentration for the constituent established from wells based on the results of the initial four independent background samples.
- For constituents for which the background level is higher than the MCL promulgated under Section 1412 of the Safe Drinking Act under 40 CFR Part 141, the background concentration.
- A level established by the EQB based upon a consideration of relevant factors, including, multiple contaminants in the groundwater, exposure threats to sensitive environmental receptors, and other site-specific exposure or potential exposure to groundwater.

After obtaining the results from sampling events, the facility must complete the following activities:

- Within 90 days of obtaining the results and on at least a semiannual basis thereafter, a minimum of one groundwater sample must be collected from each well (upgradient and downgradient) for analysis of all Appendix I parameters and the Appendix II parameters detected during the initial assessment monitoring sampling event, and record the concentrations of each constituent in the facility operating record and notify the EQB of the constituent concentration.
- Collect and analyze groundwater samples from each downgradient monitoring well for the complete list of Appendix II parameters on at least an annual basis.
- Establish background concentrations for any new constituents detected during subsequent monitoring events.

- Establish groundwater protection standards for all new constituents detected during subsequent monitoring events.

If the concentrations of all Appendix II parameters are shown to be at or below background values for two consecutive sampling events, the facility may petition the EQB to return to detection monitoring.

If the concentrations of any Appendix II parameters are above background values, but all concentrations are below the groundwater protection standard previously established in this section, using the statistical procedures described in the SAP, assessment monitoring must continue.

If one or more Appendix II parameters are detected at levels above the groundwater protection standard, the owner or operator must determine if a source other than an MSWLF unit caused the contamination or the statistically significant increase resulted from an error in sampling, analysis, statistical evaluation, or natural variation in groundwater quality. A report documenting this demonstration must be prepared and submitted for approval by the EQB. If a successful demonstration is made, the owner or operator must continue the assessment monitoring program and return to detection monitoring if the Appendix II constituents are at or below background for two consecutive sampling events. Until a successful demonstration is completed, the owner or operator must proceed with the following tasks:

- Characterize the nature and extent of the release or spill by installing additional monitoring wells as necessary.
- Install at least one additional monitoring well at the facility boundary of the facility in the direction of contaminant migration and sample according to procedures specified in the SAP.
- Notify all persons who own land or reside on land that directly overlies any part of the plume of contamination if contaminants have migrated off the site.
- Continue assessment monitoring according to the groundwater assessment monitoring plan and corrective action program.

#### **1.3.2.4 Corrective Action**

The following section is a summary of the rules regarding corrective action stated in Rule 559 of the Puerto Rico NHSWR.

The assessment of corrective action measures must include an analysis of the effectiveness of potential corrective measures in meeting all of the requirements and objectives of the remedy. The corrective measures assessment report must address at least the following items:

- The performance, reliability, ease of implementation, and potential impacts of appropriate potential remedies, including safety impacts, cross-media impacts, and control of exposure to any residual contamination
- The time required to begin and complete the remedy
- The costs associated with the implementation of the remedy
- The institutional requirements, such as federal or local permit requirements or other environmental or public health requirements, that may substantially affect implementation of the remedy

The owner or operator must submit the assessment to the EQB. Prior to filing its comments on the assessment, the EQB will hold a public meeting for interested and affected parties.

Based upon the results of the corrective measures assessment and comments from EQB, the owner or operator must provide a proposal to EQB in which a corrective measure will be selected which protects public health and the environment, attain the groundwater protection standard, minimizes the potential for future releases, and properly manages all waste materials.

The proposal must consider many factors when evaluating the long and short-term effectiveness and degree of potential success of the proposed remedy. The factors that should be considered are detailed in Rule 560.

The owner or operator may petition the EQB for an exemption from the corrective measures' action. The petition must demonstrate one of the following:

- The groundwater is additionally contaminated by another source and cleanup will not significantly reduce the risk to potential receptors.
- The constituent in question is in groundwater that is not in or connected to a drinking water source or is not migrating to a drinking water source in concentrations that would exceed the groundwater protection standard.
- Remediation of the release is technically impossible, or
- Remediation results in unacceptable cross-media impacts.

If the owner or operator is not required to completely remediate the aquifer, the EQB could require the owner or operator to reduce, control, or eliminate the source of the release, prevent exposure of contaminants to groundwater, or remediate to technically feasible levels protective of human health and the environment.

Based on the implementation and completion schedule in the remedy selection report, the owner or operator must establish and implement a corrective action groundwater monitoring program that, at a minimum, meets the requirements of the assessment monitoring program, indicates the effectiveness of the proposed remedy, and demonstrates compliance with the groundwater protection standard.

The EQB may require the owner or operator to implement an interim measure that will protect human health and the environment.

Upon the EQB's approval of the remedy, the owner or operator will be required to implement the remedy. If the owner or operator determines that the remedy is ineffective at remediating the release, the owner or operator may be required to implement an alternative remedy that would successfully remediate the release. If currently available methods are unable to practically remediate the release, the owner or operator must obtain a certificate from a qualified groundwater scientist stating that compliance cannot be achieved with

currently available methods. This certificate must be approved by the EQB. Alternative measures to protect public health and the environment and control the source of the contamination will be required and must be documented in the report submitted to the EQB. Alternative measures must be approved by the EQB prior to implementation.

The remediation will be complete when the owner or operator complies with the groundwater protection standard at all points within the plume of contamination, demonstrates that concentrations of all constituents listed in Appendix II do not exceed the groundwater protection standard for a period of 3 years using the statistical procedures listed in the SAP and demonstrates that all required actions have been completed.

Upon the completion of the remedy, the owner or operator must submit a certificate of completion to the EQB, place a copy of the certificate in the operating records, and return to detection monitoring. The certificate of completion must be signed by a representative of the owner or operator and a qualified groundwater scientist and approved by the EQB. With the approval of the certificate from the EQB, the owner and operator will be released from the financial assurance requirements for corrective actions.

\* \* \* \* \*

## **2.0 FIELD ACTIVITIES**

### **2.1 OVERVIEW**

Groundwater sampling is conducted at landfills on a regular basis to help determine the compliance of the landfill with current state, local, and federal regulations. All groundwater sampling should be done in accordance with Resource Conservation Recovery Act (RCRA) Subtitle D and Puerto Rico regulations and guidelines.

Groundwater sampling at landfills sites should consist of four basic field activities: collecting water level measurements, purging wells, obtaining field measurements of selected parameters, and collecting groundwater samples. Redevelopment of wells may also be included in the field activities.

### **2.2 PREFIELD AND POSTFIELD ACTIVITIES**

#### **2.2.1 Prefield Activities**

The project manager and the field sampling team will contact a selected laboratory, schedule the sampling event, and arrange for bottles to be obtained prior to beginning field activities. The sampling team will preschedule the needed sampling equipment.

#### **2.2.2 Postfield Activities**

At the conclusion of the field activities, the field sampling team will complete all associated paperwork and forms, including water level forms.

### **2.3 GROUNDWATER SAMPLING AND ANALYSIS**

Background groundwater samples will be collected from selected monitoring wells in four independent sampling events over a period of 2 months. At that time, the need for additional background samples will be evaluated. If additional background sampling is indicated, four additional background samples will be obtained and analyzed. If no additional background sampling is indicated, regular semiannual sampling will begin.

**TABLE 2.1**  
**Groundwater Monitoring System**  
**USNS Roosevelt Roads Sanitary Landfill**

Location	Type	Date Installed	Diameter (inches)	Top of Casing Elevation (ft.)*	Total Depth (ft. from TOP)**	Formation Screened
R7GW01	Upgradient	unknown	2	109.13	32.5	unknown,
R7GW02	Downgradient	unknown	2	105.05	27.81	unknown
R7GW04	Downgradient	unknown	2	112.46	27.41	unknown
R7GW05	Downgradient	unknown	2	114.53	31.7	Gray clay
R7GW07	Downgradient	unknown	2	114.76	28.47	Sand
R7GW08	Downgradient	unknown	2	111.39	13.89	Sand
R7GW09	Downgradient	June 1998	2	109.87	20.26	Gravel sand
R7GW10	Downgradient	June 1998	2	114.06	20.97	Sand silt
R7GW11	Upgradient	June 1998	2	110.17	15.41	Clay sand

NOTES:           \* = Elevations are based on control station EM Beach elevation of 106.360 feet  
                  \*\* = TOP (Top of Pipe)

Groundwater sampling procedures include obtaining groundwater levels, purging the well, collecting field measurements, and taking the needed groundwater and quality control samples. A list of supplies and equipment needed for the purging and sampling of groundwater is given in Appendix B along with examples of necessary forms. Table 2-1 gives the monitoring wells used in the groundwater monitoring system. Groundwater samples will be collected from the active wells whose locations are shown on Figure 2-1.

### **2.3.1 Fluid Level and Total Depth Measurements**

Fluid levels and total depths will be measured at all monitoring wells and piezometers prior to purging and sampling of monitoring wells. An electronic interface probe will be used to collect fluid level measurements. In monitoring wells or piezometers with watertight caps, measurements taken immediately after the caps are removed will be repeated at regular intervals until the readings stabilize.

All fluid levels will be measured to the surveyed reference mark on the top of the well casing. Elevations are based on control station EM Beach elevation of 106.360 feet. The reference mark will have been surveyed to within 0.01 foot relative control station EM Beach. The ground surface will have been surveyed to within 0.1 foot relative control station EM Beach.

The following procedure will be used to measure fluid levels and total depths:

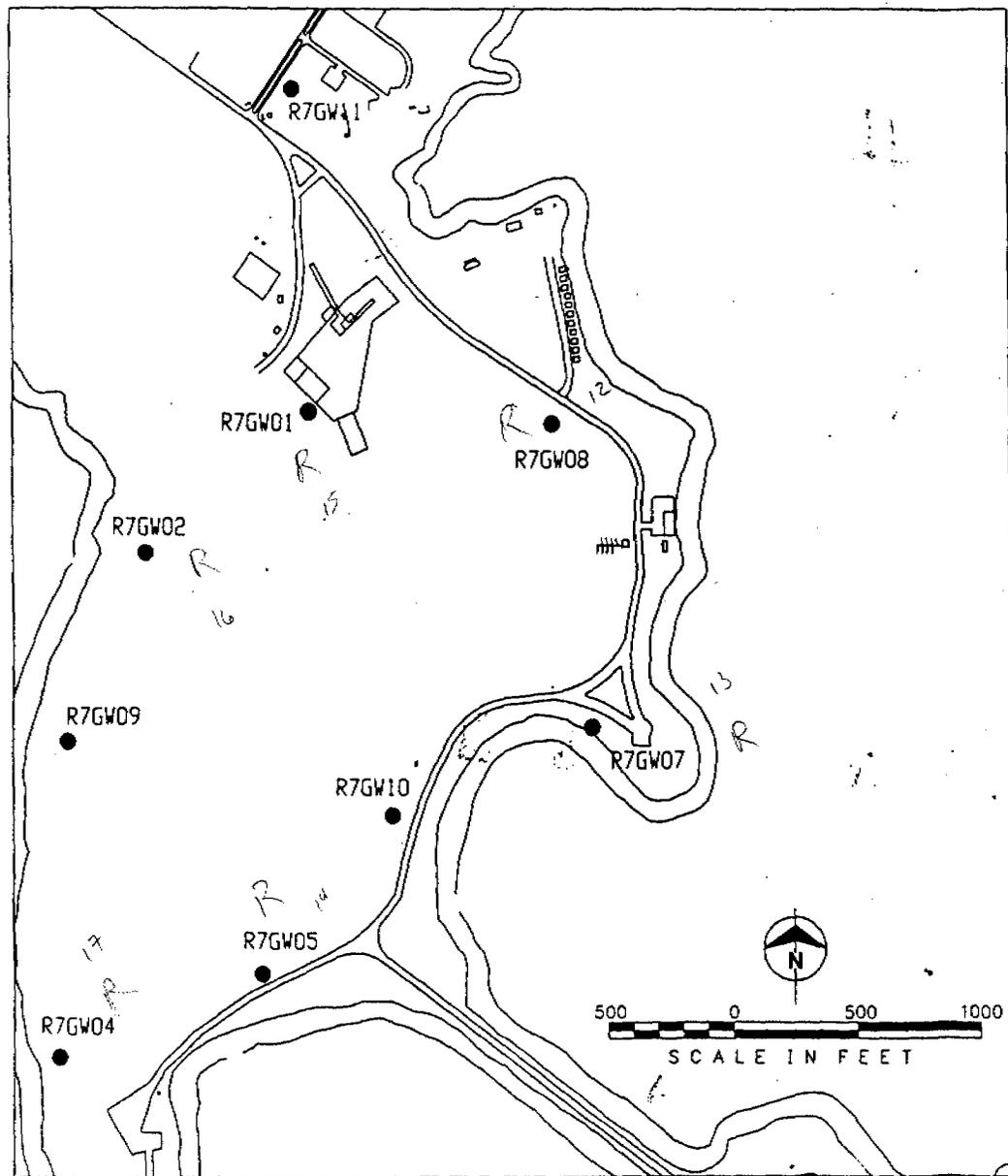
1. Decontaminate the cable and probe by spraying with distilled water and wiping with paper towels as the cable is rewound onto the reel.
2. Turn on the well probe and push the instrument test button to check the probe's batteries.
3. Lower the probe into the well by pulling the cable from the hand-held reel until the indicator light or audible signal responds.
4. Move the cable up and down while observing the indicator. Note the exact length of cable extended from the tip of the probe sensor to the top of the well casing at the reference point when the probe sensor indicates the fluid/air interface. Record the cable length to the nearest 0.01 foot, well number, time, and date of the measurement in the field logbook.

currently available methods. This certificate must be approved by the EQB. Alternative measures to protect public health and the environment and control the source of the contamination will be required and must be documented in the report submitted to the EQB. Alternative measures must be approved by the EQB prior to implementation.

The remediation will be complete when the owner or operator complies with the groundwater protection standard at all points within the plume of contamination, demonstrates that concentrations of all constituents listed in Appendix II do not exceed the groundwater protection standard for a period of 3 years using the statistical procedures listed in the SAP and demonstrates that all required actions have been completed.

Upon the completion of the remedy, the owner or operator must submit a certificate of completion to the EQB, place a copy of the certificate in the operating records, and return to detection monitoring. The certificate of completion must be signed by a representative of the owner or operator and a qualified groundwater scientist and approved by the EQB. With the approval of the certificate from the EQB, the owner and operator will be released from the financial assurance requirements for corrective actions.

\* \* \* \* \*



**MONITORING WELLS**

WELL NUMBER	NORTH	EAST	TOP OF PIPE ELEVATION (FT)	TOTAL DEPTH (FT)
R7GW01	142,163.70	785,686.16	109.13	32.5
R7GW02	141,563.38	785,081.38	105.05	27.81
R7GW09	140,831.94	784,895.00	109.87	20.26
R7GW04	139,763.02	784,926.94	112.46	27.41
R7GW05	140,036.26	785,756.69	114.53	31.7
R7GW10	140,540.45	786,342.68	114.06	20.97
R7GW07	141,146.99	787,130.54	114.76	28.47
R7GW08	142,392.23	786,919.38	111.39	13.89
R7GW11	143,505.41	785,913.68	110.17	15.41

**NOTE:**

ELEVATIONS ARE BASED ON CONTROL STATION EM BEACH ELEVATION OF 106.360 FEET.

	Figure 2-1 MONITORING WELL NETWORK ROOSEVELT RDS. NAVAL STN. PUERTO RICO
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**Table 2.2**  
**Sample Preservation and Bottle Requirements**  
**USNS Roosevelt Roads Sanitary Landfill**  
**Ceiba, Puerto Rico**

Sample Analytes	Minimum Number and Size of Sample Container	Preservative
Volatile Organics	2-40 ml glass vials with Teflon septa	HCL, pH < 2, Cool 4°C
Inorganics	1-500 ml plastic	HNO <sub>3</sub> , pH < 2, Cool 4 °C

ml = Milliliter  
C = Celsius

5. Measure the total well depth by lowering the probe to the bottom of the well. Add the length of the distance between the end of the probe and the probe sensor to the total depth measurement. Record the total depth measured at the top of the well casing at the reference point to the nearest 0.01 foot.
6. Decontaminate the probe and cable, as previously described in step 1.

Water levels should be compared with historic water levels whenever possible. If a large difference in water levels from the previous sampling event is noted, the water level should be remeasured. If the remeasurement gives the same result, the inconsistency should be noted in the field logbook.

The total depth measurement of the well should be compared with the constructed total depth. A lesser total depth measurement is an indication that sediment is accumulating in the well. Wells should be redeveloped whenever more than 10 percent of the open screen is occluded.

### **2.3.2 Well Purging**

Wells should be purged in order from least contaminated to most contaminated, based on previous laboratory analyses and/or upgradient to gradient. Wells should be purged in a manner that causes the least disturbance to the groundwater present in the monitoring well. For this reason, groundwater monitoring wells are often provided with dedicated sampling systems for purging and sampling.

#### **2.3.2.1 Purging with a Dedicated System**

Purging should be accomplished by removing water from the well at a flow rate of approximately 0.2 to 0.3 liters per minute (L/min) or less. Wells should be purged at or below their recovery rate so that the water column is not drawn down during purging. Purging should continue until the field measurements of pH, specific conductance, and temperature have stabilized to within approximately 10 percent over two readings or no improvement is achieved. Record all data on the Groundwater Sampling Data Sheet. (See Appendix B.)

Pumps in dedicated systems should be set so their intake is placed just above or within the screened interval. This eliminates the need to purge the column of static water located above the well screen. If the well screen intersects the water table, the pump intake should be placed immediately below the air/water interface.

### 2.3.2.2 Purging with a Bailer

Groundwater monitoring wells may also be purged using a bailer. Water will be removed with a bailer from the well until a minimum of three well volumes have been removed and the field parameters (pH, specific conductance, and temperature) have stabilized to within approximately 10 percent on two consecutive measurements taken not less than one well volume apart. If field measurements have not stabilized after the removal of three well volumes, additional well volumes will be removed until stabilization is obtained on three consecutive readings or no improvement is achieved. Record all generated data on Groundwater Sampling Data Sheets.

The well volume will be calculated based on the following equation:

$$V = (WL - TD) \times 0.0408 \times d^2$$

where V = well volume (gal)

WL = measured water level of the well (ft)

TD = measured total depth of the well (ft)

and d = diameter of the well casing (in)

A disposable, polyethylene bailer of known volume will be used to purge the required number of well volumes. For wells in low permeability formations that can be bailed dry, bailing is not required after the well is dry.

### 2.3.3 Field Measurements

Field measurements of temperature, pH, and specific conductivity will be collected during well purging and before the collection of samples for chemical analysis. The pH probe will be calibrated at the beginning of each day using two standard buffer solutions (pH 4 and 7). If pH readings remain at or below, recheck calibration at least twice each day. If pH readings are above 7, recalibrate the pH probe using standard buffer solutions of pH 7 and 10. Recalibrate the probe, as necessary, using pH 4 and 7 solutions when readings are at or below 7 and pH 7 and 10 solutions when readings are above 7. The conductivity meter will be checked

using a fluid of known specific conductivity at the beginning and rechecked at the end of each day to determine whether any drift occurred. All calibrations and calibration checks will be recorded in the field logbook. Extreme cold or hot weather is known to affect pH and conductivity meters. In these cases, the meters should be calibrated and checked for calibration more frequently.

The field sampling team will use the following procedure for field measurements:

1. Withdraw water from the well and pour into sample cup.
2. Read the temperature of the collected water immediately after the water is collected. Record the temperature in the field logbook or data sheet to the nearest 0.5 degree Fahrenheit (°F).
3. If using a multiple-task meter, adjust the meter for the water temperature. Measure the pH using the pH probe, and record the measurement to two decimal places in the field logbook or on the data sheet. Decontaminate the pH probe by rinsing with deionized water.
4. Measure the specific conductivity of the sample and record the measurement in the field logbook or data sheet to three significant figures. Decontaminate the probes and the sample cup by rinsing with deionized water.
5. Continue purging the well until the parameters agree to within approximately 10 percent and at least three saturated well volumes have been removed.

Record all field parameters in the field logbook or on the data sheet as they are obtained.

#### **2.3.4 Groundwater Sampling Procedure**

After the well has been purged, sampling will be conducted at the earliest time a sufficient water volume has reentered the well. If an insufficient volume of water is available within 24 hours of purging, the well shall be considered "dry" for the sampling event. VOC samples will be collected within 1 hour of purging, if possible. Field measurements (as described in Subsection 2.3.3) will be taken prior to sample collection. Samples will be collected using a pump (preferably dedicated) or by using disposable, polyethylene bailers and new rope.

Samples will be collected and containerized in the order of the volatilization sensitivity of the parameters. The wells are to be sampled for Appendix I groundwater parameters, which are found in Appendix A.

The following procedure will be used to collect groundwater samples with a bailer:

1. Slowly lower the bailer until it contacts the water surface.
2. Allow the bailer to sink and fill with a minimum of surface disturbance. Obtain groundwater samples at or immediately below the surface of the water table (less than the length of the bailer).
3. Slowly raise the bailer to the surface. Note any presence of a sheen or floating layer, odor, color, or turbidity and record on Groundwater Sampling Data Sheet.
4. Tip the bailer to allow a slow discharge from the top to flow gently down the side of the sample bottle with a minimum of entry turbulence, or use the sampling device provided with the bailer to obtain the sample from the bottom of the bailer. Completely fill sample bottles containing groundwater samples to be analyzed for volatile organic compounds (VOC's) (air bubbles should not remain in the bottle). Sample bottles with preservative should not be overfilled and, if so, should be discarded.
5. Repeat Steps 1 through 4, as needed, to acquire sufficient volume to fill all containers for the required analyses.

Procedures for sampling with a pump will vary with the type and manufacture of the pump. A generalized procedure for nondedicated equipment is to slowly lower the pump into the well to minimize degassing. If the pump was also used to purge the well, the pump should be continuously run at a low rate of approximately 0.1 L/min until the pump lines have been cleared. The groundwater sample can then be collected. Upon completion of the sampling, all nondedicated equipment should be properly decontaminated.

Groundwater samples will be placed in sample containers with appropriate preservatives. All groundwater samples will be iced immediately after collection. The intent of lowering the fluid temperature to 4°C is to minimize the amount of physicochemical change that will take place between the time the sample is collected and when it is analyzed at the laboratory.

### **2.3.5 Analysis of Groundwater Samples**

The analytical methods used for each of the Appendix I parameters in groundwater are located in Appendix A. Table 2.2 summarizes the sample bottles required for each analyte and the method of sample preservation.

### **2.3.6 Decontamination of Sampling-Contacting Equipment**

All nondisposable and nondedicated tools that contact the sample will be decontaminated prior to the collection of each sample according to ASTM D5088. This equipment includes bailers and ladles.

Decontamination rinses will be kept in labeled, plastic, spray bottles.

Sampling equipment will be decontaminated according to the following procedure:

1. Fill a nonmetallic wash tub to a depth of about 6 inches with potable water. Mix a detergent solution in the tub. The solution shall consist of 1 tablespoon of non-phosphate detergent per gallon of water.
2. Scrub all sampling equipment with a stiff-bristled brush.
3. Transfer the equipment to another wash tub partially filled with potable water.
4. Rinse the sampling equipment with potable water.
5. Rinse the equipment with deionized water.
6. Place the equipment on clean plastic, and allow it to air dry.
7. Store the equipment covered with plastic or aluminum foil upon the completion of sampling.

### 2.3.7 Redevelopment of Monitoring Wells

Redevelopment will be performed on all monitoring wells in which more than 10 percent of the open screen is occluded. Redevelopment will be used to remove fine-grained material from the well and the filter pack near the screen. Redevelopment of the monitoring wells will be accomplished using a combination of surge blocks and pumping or with a hand bailer.

Well redevelopment will proceed in the following manner:

1. Decontaminate all downhole equipment prior to beginning redevelopment.
2. Obtain an initial fluid level measurement using an electronic water level as outlined in Subsection 2.3.1.
3. Analyze an initial sample of water for pH, specific conductivity, and temperature measurements as described in Subsection 2.3.3. Note the color, odor, and turbidity of the sample in the field logbook.
4. If the well screen is set within a sand or bedrock interval, slowly lower a surge block to the top of the well intake (allowing trapped air to escape). Operate the surge block with a pumping action having a typical stroke of approximately 3 feet. Initiate surging at the top of the well intake and gradually work downward through the screened interval. Remove the surge block at regular intervals so that fine materials loosened by the surging action can be removed by pumping or bailing. Collect field measurements of pH, specific conductivity, and temperature following the removal of each saturated well casing volume of water. Repeat the cycle of surging and removal until the amount of fine-grained materials produced is negligible and the sediment has been removed from the well.

If the screen is set within a silt or clay interval, remove water from the well using a bailer. The bailer should be lowered to the bottom of the well and brought up in a manner to cause gentle surging in and out of the well. The bailer should be brought to the surface and the

water and sediment emptied. Collect field measurements of pH, specific conductivity, and temperature following the removal of each saturated well casing volume of water. Continue bailing until the sediment has been removed from the well and the field parameters, pH, specific conductivity, and temperature, have stabilized.

5. For wells that have previously shown elevated levels of regulated groundwater constituents during assessment or corrective action monitoring, collect fluids generated during redevelopment in suitable containers for later disposal.
6. Log the starting, finishing, and sampling times; field measurements of pH, specific conductivity, and temperature; volume extracted; extraction method; and initial and final fluid levels in the field logbook.

## **2.4 GROUNDWATER QUALITY CONTROL SAMPLES**

One duplicate sample and one matrix spike (MS) and duplicate (MSD) will be collected for every 20 samples. At a minimum, one duplicate sample and one matrix spike and matrix spike duplicate will be collected during each sampling event. Trip blanks will accompany each cooler containing samples for VOC analysis.

### **2.4.1 Duplicate Samples**

Each duplicate sample will be obtained at the same time and analyzed for the same set of parameters as the investigative sample it is intended to duplicate. The contents of two consecutive bailer volumes will be individually analyzed as original and duplicate samples. The first bailer volume will serve as the original sample and the second as the duplicate. If more than one bailer is required to fill the sample jars, the original sample jars will be filled first, and the separate bailers of water will then be collected to complete the duplicate samples. Original and the duplicate samples will be placed in identical containers and preserved in the same manner. Duplicate samples will be identified with unique sample identification numbers. Sample points where duplicates are collected will be documented in the field logbook.

## **2.4.2 Matrix Spikes and Matrix Spike Duplicates**

Groundwater samples will be collected in triplicate at certain locations for the completion of matrix spikes and matrix spike duplicates. The three samples will be identified as the sample, the matrix spike, and the matrix spike duplicate.

## **2.4.3 Trip Blanks**

Trip blanks for VOCs in groundwater will be prepared by the laboratory and accompany sample containers transported to the site. The trip blanks will remain on the site during sampling. One trip blank set will be included in each cooler containing samples for VOC analysis to determine whether VOCs are introduced into groundwater samples as a result of on-site conditions, laboratory operations, or conditions during sample shipment.

## **2.5 SAMPLE CUSTODY AND DOCUMENTATION PROCEDURES**

Each sample or field measurement must be properly documented to facilitate timely, correct, and complete analyses and support actions concerning the site. The documentation system provides a means to identify, track, and monitor each individual sample from the point of collection through final reporting of the data. Specific documentation requirements are described in the following sections. Sample documents forms are included in Appendix B.

### **2.5.1 Documentation Procedures**

A suitable work area will be established with sufficient space available for processing forms and packaging samples. After all sample documentation has been completed and before the samples are prepared for shipping, a field team member will cross-check the data on all forms and labels and compare the data to the logbook or data sheet entries.

The following procedure is given as a general reference for completing the sample documentation:

1. Determine the samples to be packaged and shipped that day and the laboratory to be used.
2. Complete a shipping bill (if applicable) and enter the shipping record number in the field logbook.

3. Complete a chain-of-custody record.
4. Prepare samples for shipment.

### **2.5.2 Field Logbook Record**

All information pertinent to the groundwater sampling event will be recorded in a bound logbook with consecutively numbered pages. All entries in logbooks will be made in waterproof ink, and corrections will consist of line-out deletions that are initialed and dated. The person responsible for the entries will sign and date each page (or entry) after entering it in the logbook.

No general rules can specify the exact information that must be entered in a logbook for a particular site. However, the logbook should contain sufficient information so that sampling activities can be reconstructed, if necessary. Logbooks will be kept in a field team member's possession or a secure place during the investigation. Following the sampling event, logbooks will become part of the final file. A list of typical field logbook entries is as follows:

- Date
- Weather conditions
- Names of samplers
- Calibration record of field test equipment
- Monitoring well number
- Water level and total depth measurements with measurement technique
- Well purge equipment and technique
- Purge volume and time
- Initial and subsequent field measurements for each well volume of groundwater removed
- Identification number of sample
- Time of collection
- Sample withdrawal procedure/equipment
- Types and number of sample containers
- Parameters requested for analyses
- Preservatives used

- Sample description (color, odor, etc.)
- Field observations on sampling event
- Sample shipment information, name of carrier, air bill number, and shipment date and time

As an alternative, Groundwater Sampling Data Sheets may be used to record the details associated with purging and sampling. An example of this form appears in Appendix B.

### **2.5.3 Chain-of-Custody Record**

The chain-of-custody record will be employed as physical evidence of sample custody. The sample team will complete a chain-of-custody record to accompany each sample shipment from the field to the laboratory.

The custody record will be completed using waterproof ink. Corrections will be made by drawing a line through, initialing, and dating the error and entering the correct information. Erasures will not be permissible.

The following typical information is to be included in the chain-of-custody record:

- Sample numbers
- Signatures of samplers
- Date and time of collection
- Sample type (water)
- Identification of monitoring wells
- Number of containers
- Parameters requested for analysis
- Signatures of persons involved in the chain of possession
- Inclusive dates and times of possession
- Notations regarding compromise of sample integrity, such as broken seals, bottles, etc.
- Notation regarding the presence or absence of ice when the cooler is opened at the laboratory.

After completing a chain-of-custody record using the above procedure, the original signature (top) copy of the record will be enclosed in a plastic bag (with any other sample documentation) and secured to the inside lid of the cooler. An example of a typical chain-of-custody is provided in Appendix B.

## **2.5.4 Sample Labels**

Each sample removed from the site and transferred to a laboratory for analysis will be identified with a sample label containing specific information regarding the sample. Each completed sample identification label will be securely fastened to the sample container. All sample seals will be completed in waterproof ink. An example sample label is provided in Appendix B.

## **2.5.5 Custody Seals**

A custody seal will be used to preserve the integrity of the sample from the time it is collected until opened in the laboratory. Seals must be attached so that it is necessary to break the seals to open the sealed container. All samples for the site will be shipped in coolers. Each cooler will usually be sealed on two opposite sides with custody seals. As long as custody records are sealed inside the sample cooler and custody seals remain intact, commercial carriers are not required to sign the custody form.

## **2.6 SAMPLE CONTAINER HANDLING, PACKAGING, AND SHIPPING**

Sample packaging and shipping procedures are based on the United States Environmental Protection Agency (USEPA) specifications, as well as U.S. Department of Transportation (DOT) regulations (49 Code of Federal Regulations (CFR) Parts 172 and 173). Samples will be packed and shipped according to the requirements for low hazard level samples. All samples will be packaged and transported within 1 day of collection.

During field activities, loose samples should be handled in the same manner as packed samples. The samples, after being obtained and labeled, should be wrapped with protective packing material or stored in foam holders. At all times, ice in double sealable plastic bags should be kept in the cooler to reduce the temperature of the samples as quickly as possible. Ice should be replenished as needed. The procedures outlined below are applicable to the case where the samples are relinquished to an overnight delivery service. If the samples are delivered directly to the analytical laboratory, the packaging requirements can be reduced appropriately.

The steps outlined below will be followed to pack low hazard samples:

1. Arrange sample containers in groups by sample number. However, group VOC samples so they can be placed into common shipping containers.
2. Arrange containers in front of the assigned coolers.
3. Pack the containers in the foam holders provided with the jars or wrap each glass sample container with protective packing material. Tape the packing material to the containers and secure in place.
4. Place approximately 2 inches of packing material in the bottom of the cooler for cushioning.
5. Line the cooler with a large trash bag.
6. Place sample containers inside the trash bag in the cooler.
7. Seal the trash bag with tape.
8. Add ice packaged in double sealable plastic bags and fill the remaining volume of the cooler with packing material. Do not allow sample containers to contact the ice directly.
9. Record the time the cooler is relinquished to the analytical laboratory or an overnight delivery service in the field logbook.
10. Separate copies of forms. Seal paper copies in a large, sealable, plastic bag, and tape to the inside lid of the cooler.
11. Tape the cooler drain shut.
12. Close the lid and latch the cooler. Tape the cooler shut on both ends, making several revolutions with the strapping tape. Do not cover labels.

13. Place the shipping bill with the contracted laboratory's address on top of the cooler.
14. Put "This Side Up" labels on both ends of cooler lid and up arrow symbols on all four sides of the cooler.
15. Affix custody seals over lid openings (front right and back left corners of cooler). Cover seals with clear, plastic tape.
16. Maintain a file of all sample documentation.

\* \* \* \* \*

### 3.0 QUALITY ASSURANCE/QUALITY CONTROL

Data collected during quarterly groundwater monitoring activities will be used to determine whether assessment monitoring is warranted. To satisfy this use, analytical data should meet the Level III requirements defined in the USEPA publication, Data Quality Objectives for Remedial Response Activities - Development Process (DQORRA; 1987). Level III is defined in this document as "... analyses performed in an off-site analytical laboratory ... using USEPA procedures other than Contract Laboratory Program (CLP)" and is typically accepted as those methods found in SW-846.

To provide the proper level of confidence, it is critical that only valid data is used. To this end, field and laboratory quality assurance/quality control (QA/QC) procedures have been established. This chapter presents the data quality objectives (DQOs), field and laboratory QA/QC requirements, and data validation components.

#### 3.1 DATA QUALITY OBJECTIVES

Precision, accuracy, representativeness, completeness, and comparability (PARCC) are all aspects of data quality.

##### 3.1.1 Precision

Precision is a measure of the reproducibility of the measurements made under a set of conditions. Specifically, it is a quantitative measure of the variability of a group of measurements compared to their average value.

Precision is assessed by evaluating duplicate sample results and can be expressed as the relative percent difference (RPD) as follows:

$$RPD = \frac{|(D_1 - D_2)|}{(D_1 + D_2)/2} \times 100$$

Where:  $D_1$  = Original Sample Value  
 $D_2$  = Duplicate Sample Value

If variability of a group of measurements is not present compared to their average value, the RPD equals zero.

Precision quality control (QC) procedures for field measurements consist of taking multiple readings.

Both overall and analytical precision are examined for analyses requiring the use of an off-site commercial laboratory. Field duplicates will be collected to evaluate the overall precision of field sampling and laboratory analytical methods.

Analytical precision is assessed from MS/MSD results. The sample collector will collect extra sample material from certain sample locations at the minimum duplicate sample frequency specified by Chapter 1 of SW-846 (i.e., once every 20 samples). Sample material from these locations will be designated on the chain-of-custody form as requiring laboratory MS/MSD analyses.

The precision goals for duplicate analyses are modeled on the criteria for inorganic laboratory duplicates presented in the USEPA's Laboratory Data Validation Functional Guidelines for Evaluating Inorganics Analyses (LDVI; 1988).

### **3.1.2 Accuracy**

Accuracy measures the bias of a measurement system. Possible sources of errors include the sampling process, field contamination, preservation, handling, sample matrix, sample preparation, and analytical techniques.

QC procedures for field measurements consist of initial and periodic instrument calibrations for accuracy.

Several different types of QC samples are collected to accompany samples requiring analyses at an off-site commercial laboratory. Sources of potential contamination (both field and laboratory based) are examined by the use of blank samples (e.g., equipment rinsate, laboratory method, and trip blanks). Such blanks are collected/created at the minimum frequency specified in Chapter 1 of SW-846 (i.e., once every 20 samples). The amount of contamination detected in any blank should not exceed the more stringent of the following criteria:

- Method blank criteria in Chapter 1 of SW-846
- Ten times the concentration in the associated field samples

Interferences from the sample matrix or errors introduced by the analytical process may be assessed by examining spike sample results MS, surrogate, and laboratory control samples (LCS)). For spike samples, accuracy is expressed in terms of percent recovery (REC), which measures the degree of agreement between a measurement and its true value. The REC is calculated as follows:

$$REC = \frac{|SSR-SR|}{SA} \times 100$$

Where: SSR = Spike Sample Results  
SR = Sample Results (assumed to be zero for surrogates)  
SA = Spike Added (zero for commercially purchased LCS)

Perfect accuracy is defined as 100 REC.

Spike sample results will be compared to QC criteria established in the applicable analytical methods or to laboratory-developed QC criteria, as appropriate. It is possible for spike RECs to be significantly below their minimum QC limits. Such hyposensitivity, as defined by the LDVI and by the USEPA's National Functional Guidelines for Organic Data Review (NFGO; 1991), include the following examples:

- Inorganic MSREC values below 30 percent
- Surrogate REC values below 10 percent
- Inorganic LCSREC values below 50 percent

In such cases, some or all of the associated field samples results may not meet the accuracy DQO because the possibility of false negatives exists.

### **3.1.3 Representativeness**

Representativeness qualitatively expresses the degree to which sample analytical results precisely and accurately represents site conditions. The representativeness DQO was considered during the planning stages and is reflected in several aspects of the sampling approach: number of samples, sample locations, sampling techniques, and analytical parameters.

Analytical results will fail to meet the representativeness DQO if gross precision or accuracy QC problems exist.

### **3.1.4 Completeness**

Completeness defines the percentage of completed measurements judged to be valid. Sufficient amounts of valid data must be generated to make technical decisions. Field completeness is assessed by comparing the number of samples collected to the number of samples planned for collection. Laboratory completeness is assessed by comparing the number of samples with valid data to the number submitted for chemical analysis. Laboratory completeness is reduced by the following mechanisms:

- Data were qualified as unusable (R) during data validation based on gross precision or accuracy QC problems
- Holding times were exceeded

Minimum completeness objectives are 80 percent for field and laboratory measurements.

### **3.1.5 Comparability**

Comparability qualitatively expresses how data developed during the groundwater sampling activities compares with applicable criteria. Data collected semiannually during this sampling event can be considered comparable to other sampling event data collected following the sampling procedures outlined in this work plan and analyzed using the same methods from SW-846.

### **3.2 LABORATORY QA/QC**

The Quality Assurance (QA) Plan from the laboratory initially contracted to perform analytical services (Caribtec Laboratories, Inc.) is attached as Appendix C. If in the future an alternate laboratory is selected, the selected laboratory's QA Plan will be submitted. The alternate laboratory's QA Plan will contain requirements at least as stringent as these identified in this plan, including Appendix C.

### **3.3 FIELD QA/QC**

Field QA/QC procedures were previously discussed in the sampling procedures and DQO sections. In summary, field QA/QC procedures include the following activities:

- Calibrating field instruments
- Taking multiple readings of field measurements
- Collecting material for QC samples (e.g., MS/MSD, field duplicate, equipment rinsate blank) at a minimum frequency of one per 20 sample
- Preparing and handling QC sample material in the same manner as field samples
- Including a trip blank with every cooler shipped with VOCs to the laboratory or at a minimum frequency of one per 20 samples, whichever is more frequent

### **3.4 DATA VALIDATION**

Data validation procedures determine whether individual project data are usable, usable with qualifications, or unusable. National guidance documents do not exist concerning the validation of groundwater data generated under (RCRA). Therefore, this sampling plan will adapt the principles presented in two USEPA Contact Laboratory Program (CLP) documents, the LDVI and NFGO, to acquire the semiannual groundwater data.

#### **3.4.1 Organic Constituents**

Guidelines for performing validation of organic analytical data are provided in the USEPA's NFGO. Personnel conducting the validation will use this guideline when validating organic analytical data for the following parameters:

- Holding times

- Laboratory method blanks
- Equipment rinsate blanks
- Trip blanks
- Surrogates
- MS/MSDs
- Laboratory control samples
- Field duplicates
- Quantitation limits

### **3.4.2 Inorganic Constituents**

Guidelines for performing validation of inorganic analytical data are provided in the USEPA's LDVI.

Personnel conducting the validation will use those guidelines when validating inorganic analytical data for the following parameters:

- Holding times
- Laboratory method blanks
- Equipment rinsate blanks
- MS/MSDs
- Laboratory control samples
- Field duplicates
- Detection limits

### **3.4.3 Data Qualification**

Blank results will be examined qualitatively and quantitatively. False positives may be qualified as undetected (U\*) based on laboratory method blank results, per guidance in the LDVI or NFGO. Under no other circumstances will groundwater data be corrected. If a blank's concentration of an analyte exceeds 10 times the concentration in its associated field sample, the field sample will be noted as requiring resampling/reanalysis.

Extremely poor recoveries for a surrogate, MS sample, or LCS may result in data being qualified as estimated (J\*) or unusable (R).

\*\*\*\*\*

## 4.0 STATISTICAL ANALYSIS OF DATA

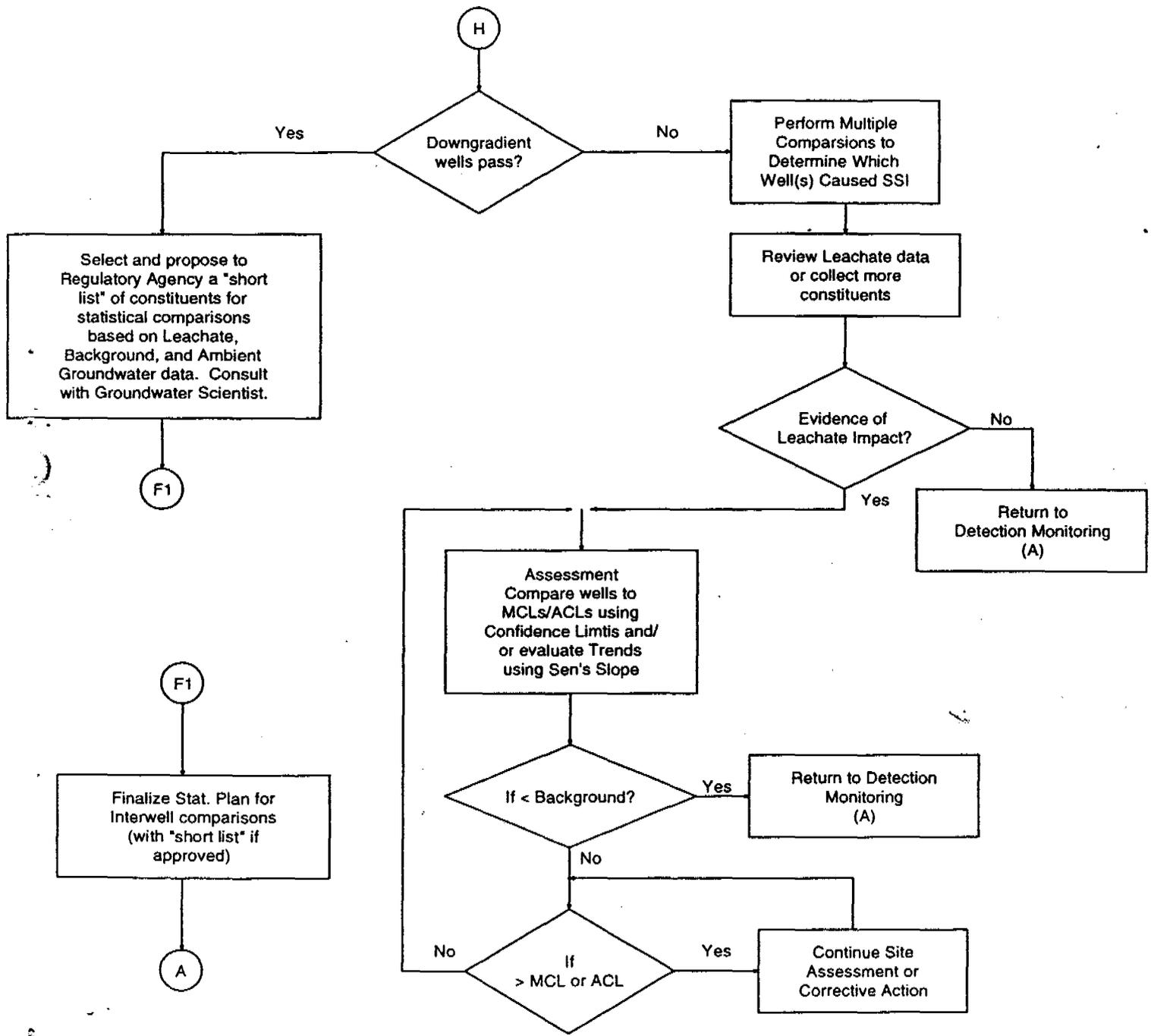
The groundwater monitoring data that will be collected in accordance with this monitoring plan under RCRA Subtitle D must be statistically evaluated. This section, unlike prior sections in this report, does not constitute a complete set of instructions, but instead is a guide to design a statistical analysis procedure. The final statistical detection monitoring plan cannot be fully specified until the background samples for the required list of constituents are available. The following sections provide an outline of the general statistical procedure for groundwater monitoring under the Puerto Rico NHSWR. A flowchart (see Figure 4-1) is provided at the end of this section to summarize the statistical procedure to be used for the site. As mentioned previously, after four sampling events are completed, an evaluation of the need for four additional background samples will be performed.

The steps that will be followed to conduct a statistical analysis of groundwater quality data are described in Section 4.1. The statistical methods that will be used are summarized in Section 4.2 and discussed in detail in the EPA "Interim Final Guidance" (IFG) (USEPA, 1989) and "Addendum to the Interim Final Guidance" (AIFG) (USEPA, 1992). These documents should not be followed uncritically. Statistical knowledge and insight will be required to design an appropriate statistical analysis procedure (Gibbons, 1993).

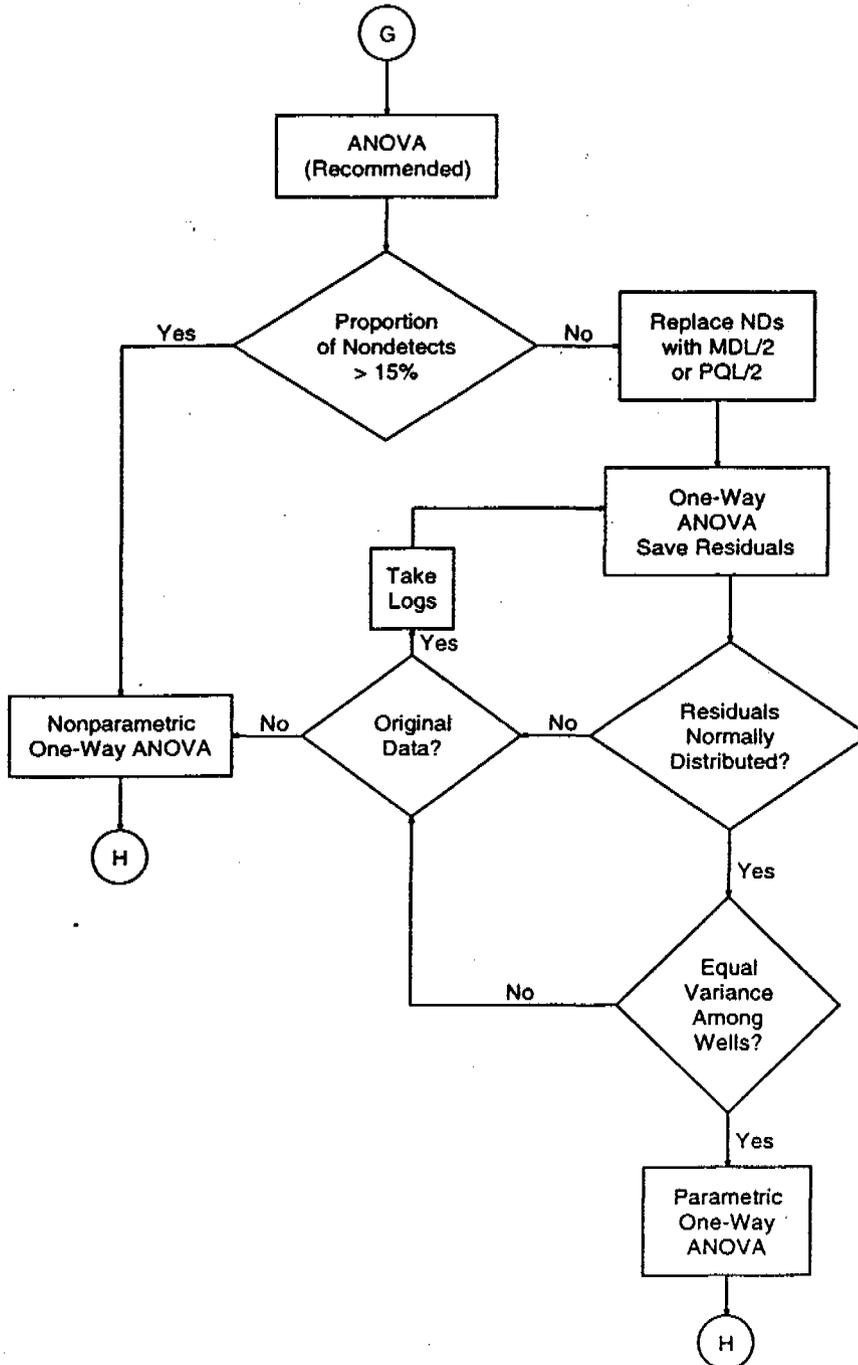
### 4.1 DATA DISTRIBUTION

The Puerto Rico NHSWR allow for various methods for comparing concentrations of constituents measured in monitoring wells to background concentrations, including analysis of variance, tolerance limits, prediction limits, and control charts. In the context of groundwater monitoring at waste disposal facilities, legislation has required statistical methods as the basis for investigating potential environmental impacts due to waste disposal facility operations. Owners/operators must perform a statistical analysis on a semiannual basis. A statistical test is performed on many constituents (i.e., 6 to 212) for many wells (4 to more than 10). The result is potentially hundreds (in some cases a thousand or more) of statistical comparisons performed for each monitoring event. Even if the false positive rate for a single test is small (e.g., 1 percent), the possibility of failing at least one test on any one monitoring event is virtually guaranteed.

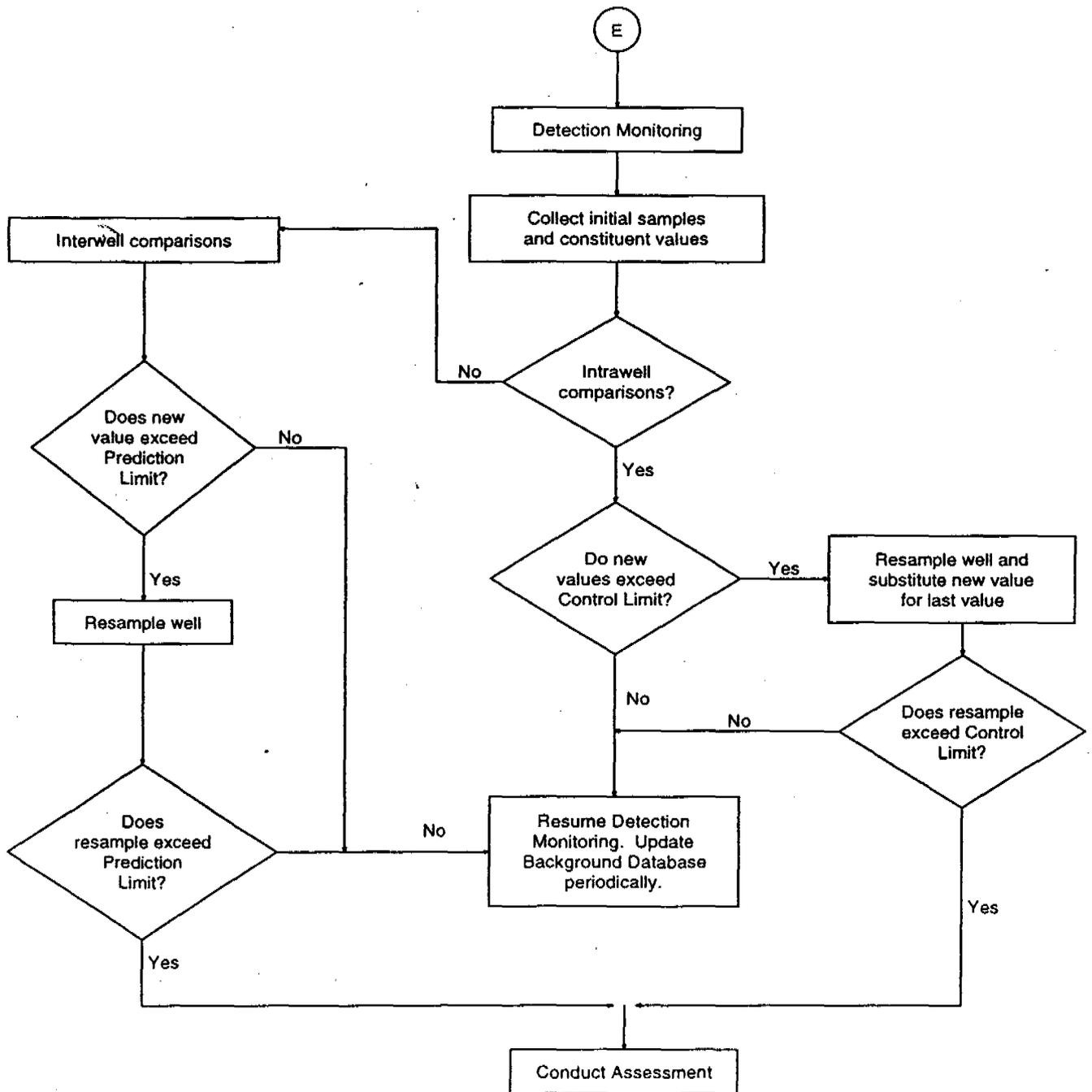
**Figure 4-1**  
**Development of a Statistical Detection Monitoring Plan**  
**(Continued)**



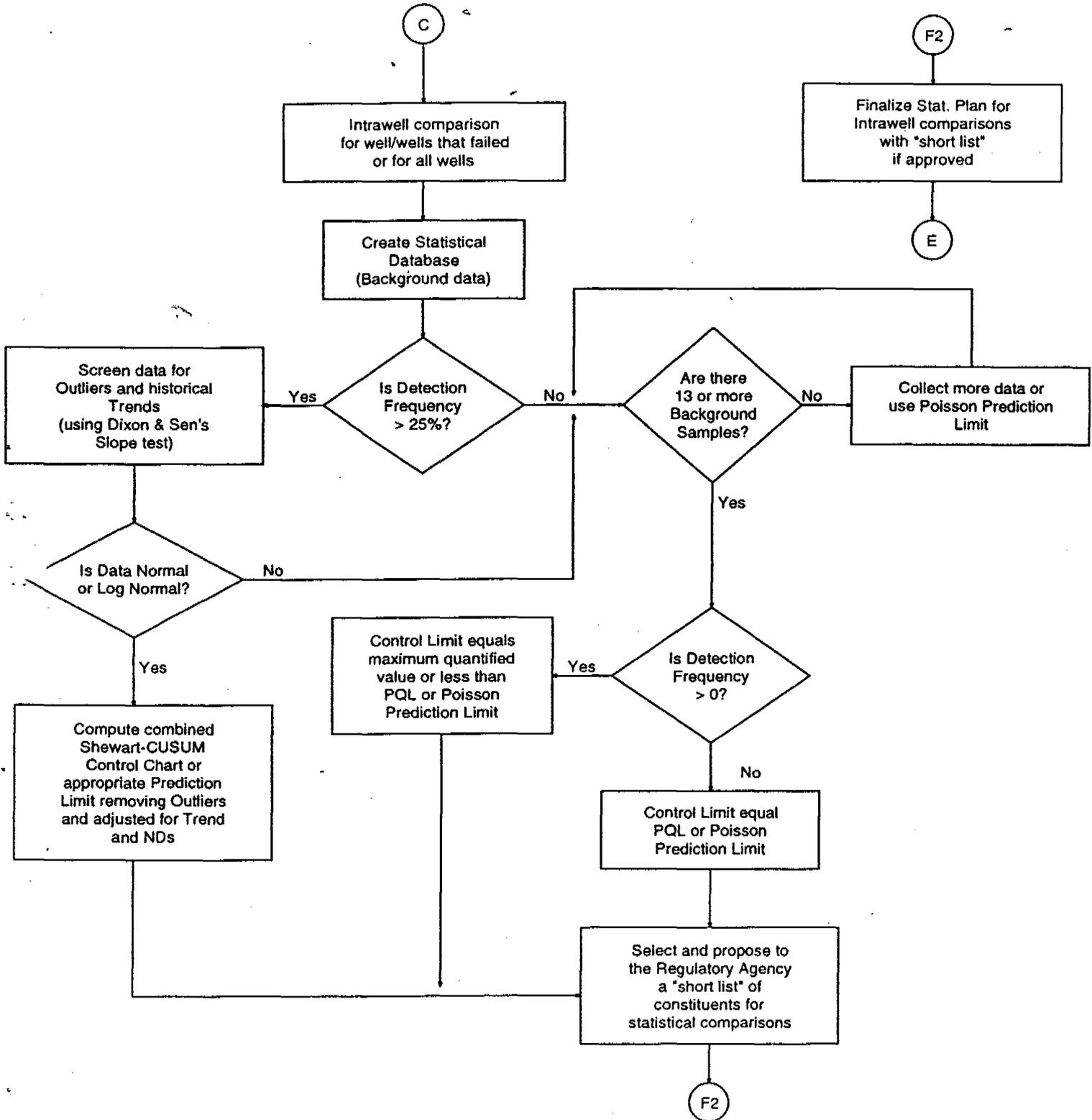
**Figure 4-1  
Development of a Statistical Detection Monitoring Plan  
(Continued)**



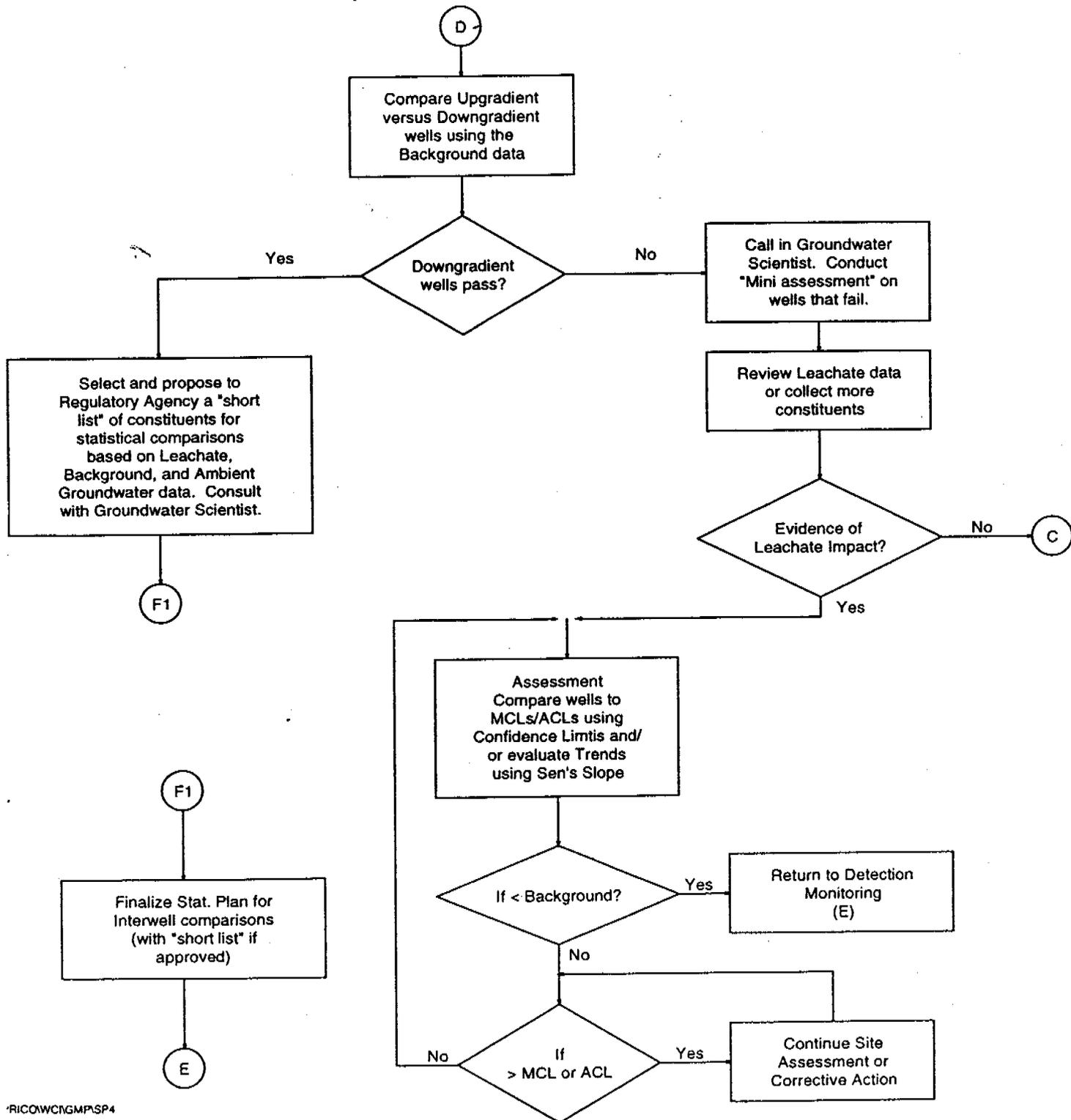
**Figure 4-1  
Development of a Statistical Detection Monitoring Plan  
(Continued)**



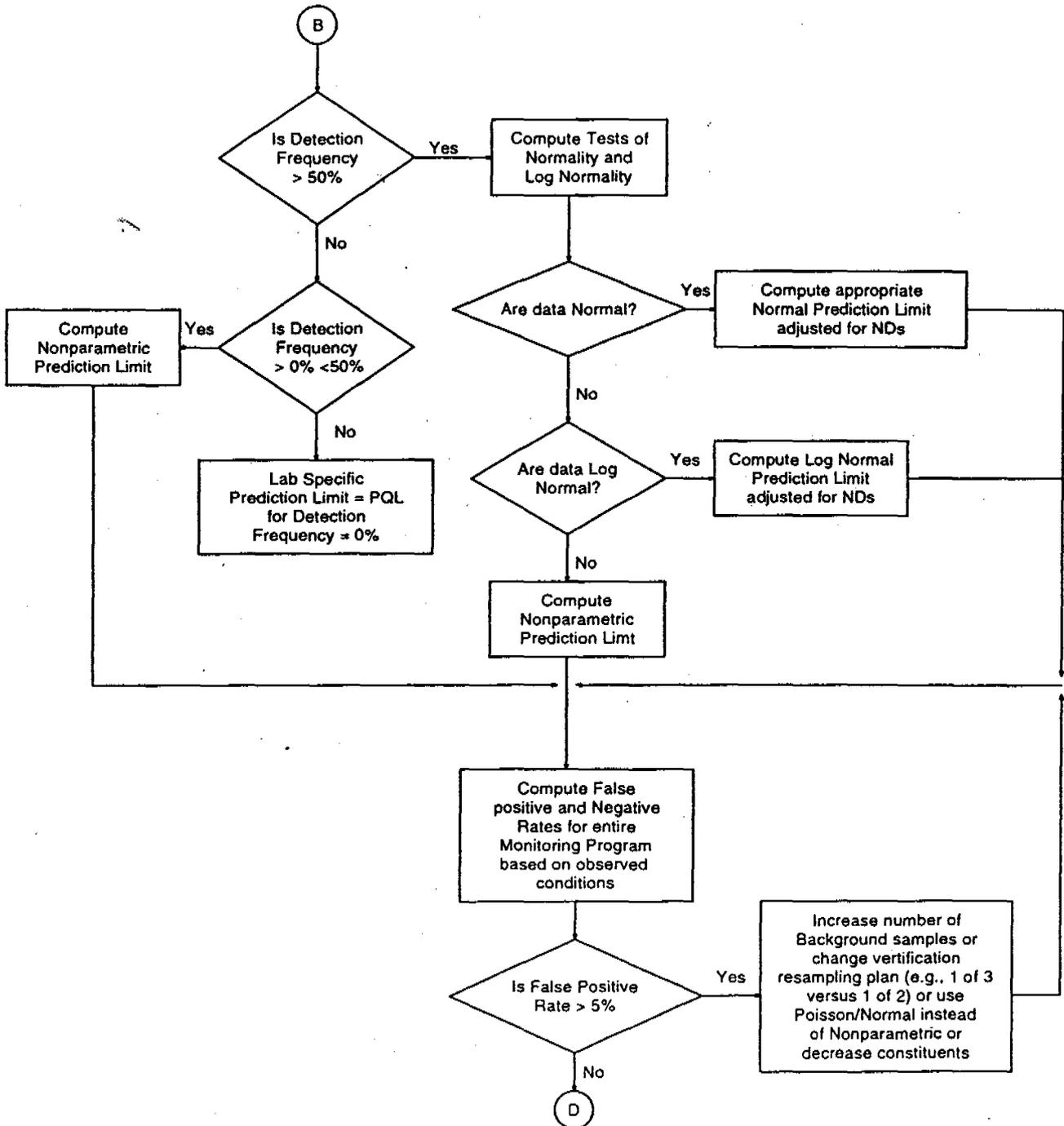
**Figure 4-1**  
**Development of a Statistical Detection Monitoring Plan**  
**(Continued)**



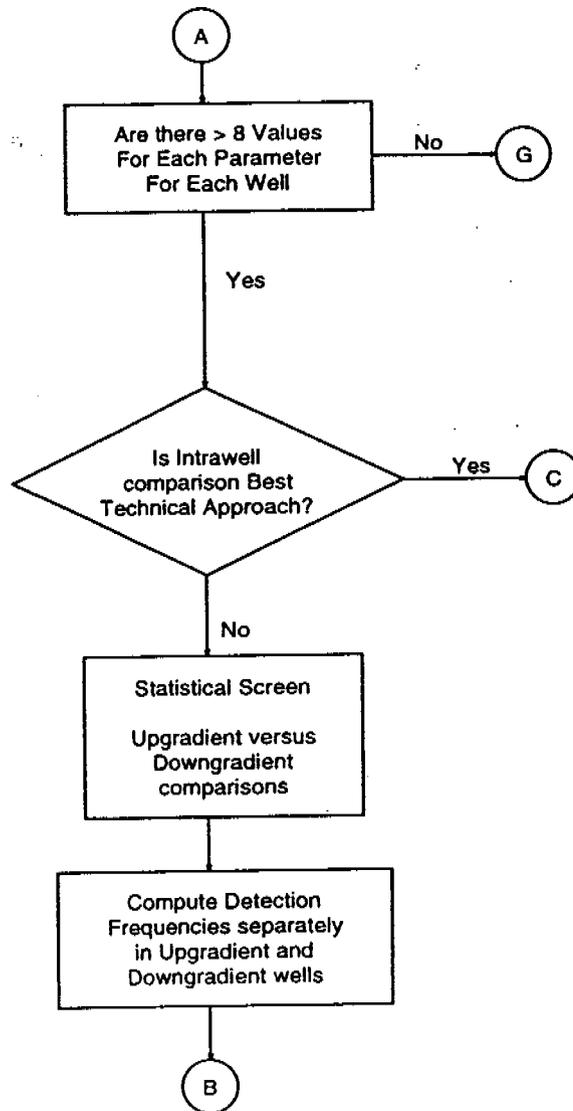
**Figure 4-1  
Development of a Statistical Detection Monitoring Plan  
(Continued)**



**Figure 4-1**  
**Development of a Statistical Detection Monitoring Plan**  
**(Continued)**



**Figure 4-1**  
**Development of a Statistical Detection Monitoring Plan**  
**(Continued)**



In the following sections, a statistical plan is developed that includes an effective verification resampling plan and selection of appropriate statistical methods (e.g., ANOVA, parametric and nonparametric prediction limits or control charts for intrawell comparisons) that detect contamination and do not falsely conclude that the groundwater is contaminated. Statistical significance of contamination detection cannot be properly determined without verification resampling.

In general, it is unwise to perform statistical computations on less than eight background samples. However, the analysis of variance (ANOVA) method may be used with as few as four background samples per well. Prediction limits generally require a minimum of eight samples. This may be four quarterly samples in each of two upgradient wells or eight samples taken from each well where intrawell comparisons will be performed. To use fewer samples will lead to high false negative rates due to the large size of the prediction limit (i.e., with four samples and three degrees of freedom, the uncertainty in the true mean and standard deviation ( $\mu$  and  $\sigma$ ) given the sample based estimates ( $\bar{x}$  and  $s$ ) is quite large, resulting in extremely high prediction limits). Conversely, with only a few background measurements, knowledge of the true sampling variability, distributional form, and detection frequency may be completely inaccurate and lead to a high false positive rate.

Another major concern is whether the upgradient wells accurately characterize the natural spatial variability observed in the downgradient wells. The alternative is to perform intrawell comparisons, which are generally preferable. However, it must first be demonstrated that the well has not been impacted by the sanitary landfill. To demonstrate this, test the appropriateness of upgradient versus downgradient comparisons for each well and constituent. Where intrawell comparisons are more applicable, demonstrate the absence of any significant trend in that well and constituent and demonstrate the absence of any constituents of concern (e.g., volatile organic priority pollutant list compounds or other constituents that characterize the leachate from the facility).

When justified, intrawell comparisons are more powerful than their interwell counterparts because they completely eliminate the spatial component of variability. Due to the absence of spatial variability, the uncertainty in measured concentrations is decreased, making intrawell comparisons more sensitive to real releases (i.e., false negatives). False positive results due to spatial variability are eliminated.

### **4.1.1 Detection Monitoring**

The following sections describe the procedures used to statistically evaluate the analytical data for each parameter. Either an interwell (upgradient wells versus downgradient wells) or intrawell comparison can be used to evaluate the data.

#### **4.1.1.1 Interwell Comparisons**

Upgradient versus down gradient comparisons can be made using either ANOVA or prediction limit methods. If there are greater than eight parameter values for each well, the prediction limit method is preferred over the ANOVA method.

##### **4.1.1.1.1 Analysis of Variance Method**

The following procedures are used to perform an ANOVA analysis on the analytical data:

- Determine the proportion of nondetects. If there is greater than 15 percent nondetects, perform a Kruskal-Wallis test (a nonparametric, one-way ANOVA) on the original analytical data as described later in this section. Otherwise, replace the nondetects with a value equal to half of the practical quantitation limit (PQL).
- Determine if the data is normal or lognormal. After replacing the nondetect values, perform a one-way ANOVA and save the residuals. Determine if the residuals are normally distributed using the Shapiro-Wilk test (for up to 50 samples) or Shapiro-Francia test (for 51 to 99 samples). If the residuals are not normally distributed, calculate the natural logarithm of the original analytical data, perform a one-way ANOVA, and save the residuals. If the residuals of the lognormal data are not normally distributed using the Shapiro-Wilk or Shapiro-Francia tests, then perform a Kruskal-Wallis test on the original analytical data.
- Determine if there are equal variances among the wells. If the residuals of the one-way ANOVA are normally distributed (after performing a one-way ANOVA on the actual data or the natural logarithm of the data), determine if there is equal variance among the wells using

Levene's test. If there is equal variance among the wells, perform a parametric, one-way ANOVA on the original analytical data using a 5 percent false positive rate, otherwise perform a Kruskal-Wallis test on the original data using a 5 percent false positive rate.

- Determine if there is a statistical significant increase (SSI). Compare the results of the parametric, one-way ANOVA or the Kruskal-Wallis tests to tabulated values to determine if an SSI occurred. If there is no evidence of an SSI, proceed with the detection monitoring program. If there is evidence of an SSI, determine which well(s) caused the SSI.
- Determine which well caused the SSI. If it is determined there is an SSI for a group of wells, perform a post-hoc analysis using multiple comparisons with a 1 percent false positive rate for each well to determine which well(s) caused the SSI.

#### **4.1.1.1.2 Prediction Limit Method**

The following procedures are used to perform a prediction limit analysis on the analytical data:

- Determine the detection frequency to select the specific prediction limit test to perform.
  - If the detection frequency is greater than 50 percent, determine if the data is normal or lognormal. If the data is normal, compute normal prediction limit [40 CFR 258.53(h)(4)], select the false positive rate based on number of wells, constituents and verification resamples [40 CFR 258.53 (h)(2)] and adjust the estimates of sample mean and variance for nondetects. If the data is lognormal, compute a lognormal prediction limit [40 CFR 258.53(h)(1)]. If the data is neither normal nor lognormal, compute nonparametric prediction limit [40 CFR 258.53(h)(1)] unless background is insufficient to achieve a 5 percent site-wide false positive rate. In this case, use a normal distribution [40 CFR 258.53(h)(1)].

- If the background detection frequency is greater than zero but less than 50 percent, compute a nonparametric prediction limit and determine if the background sample size will provide adequate protection from false positives. If insufficient data exists to provide a site-wide false positive rate of 5 percent, collect more background data [40 CFR 258.53(h)(1)].
  
- If the detection frequency equals zero, use the laboratory specific PQL. This only applies to wells and constituents that have at least 13 background samples. Thirteen samples provide a 99 percent confidence nonparametric prediction limit with one resample (see Table 4.1). If less than 13 samples are available, more background data must be collected. As an alternative to the above option, use a Poisson prediction limit, which can be computed from only eight background measurements regardless of the detection frequency (USEPA, 1992 Section 2.2.4).
  
- If downgradient wells fail the prediction limit test, determine the cause and effect as listed below.
  - If the downgradient wells fail because of natural or off-site causes, select constituents for intrawell comparisons [40 CFR 258.53(h)(3)].
  
  - If site impacts are found, a site plan for assessment monitoring and detection monitoring (at unaffected wells) may be necessary [40 CFR 259.55].

#### **4.1.1.2 Intrawell Comparisons**

When justified, intrawell comparisons are more powerful than interwell comparisons because they account for spatial variability in groundwater chemistry. Intrawell comparisons may be justified for those facilities that meet one or more of the following criteria:

- Monitoring wells were installed prior to disposal of waste.
- There is no definable gradient on the site or the site has an inward gradient.

Table 4.1

Probability that the First Sample or the Verification Resample Will be Below the Maximum of "n" Background Measurements at Each of "k" Monitoring Wells for a Single Constituent

Previous n	Number of Monitoring Wells (k)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
4	.933	.881	.838	.802	.771	.744	.720	.698	.679	.661	.643	.630	.617	.604	.592
5	.952	.913	.879	.849	.823	.800	.779	.760	.742	.725	.711	.697	.684	.672	.661
6	.964	.933	.906	.882	.860	.840	.822	.803	.789	.774	.761	.748	.736	.725	.714
7	.972	.947	.923	.905	.886	.869	.853	.838	.823	.812	.799	.786	.777	.766	.757
8	.978	.958	.939	.922	.906	.891	.878	.864	.852	.841	.830	.819	.809	.800	.791
9	.982	.965	.949	.935	.921	.908	.896	.883	.874	.864	.854	.844	.835	.827	.818
10	.985	.971	.957	.945	.933	.922	.911	.901	.891	.882	.873	.863	.853	.849	.841
11	.987	.975	.964	.953	.942	.933	.923	.914	.906	.897	.889	.882	.874	.867	.860
12	.989	.979	.969	.959	.950	.941	.933	.923	.917	.910	.902	.896	.889	.882	.876
13	.990	.981	.973	.964	.956	.948	.941	.934	.927	.920	.914	.907	.901	.893	.889
14	.992	.984	.976	.969	.961	.954	.948	.941	.933	.929	.923	.917	.912	.906	.901
15	.993	.986	.979	.972	.966	.959	.953	.947	.942	.936	.931	.926	.920	.915	.910
16	.993	.987	.981	.975	.969	.964	.958	.953	.948	.943	.938	.933	.928	.923	.919
17	.994	.988	.983	.978	.972	.967	.962	.957	.953	.948	.943	.939	.935	.930	.926
18	.995	.990	.985	.980	.975	.970	.966	.961	.957	.953	.949	.944	.940	.937	.933
19	.995	.991	.986	.982	.977	.973	.969	.965	.961	.957	.953	.949	.946	.942	.938
20	.996	.991	.987	.983	.979	.975	.972	.968	.964	.960	.957	.953	.949	.946	.942
21	.997	.994	.992	.989	.986	.984	.981	.978	.976	.973	.971	.968	.966	.964	.961
22	.997	.994	.992	.989	.986	.984	.981	.978	.976	.973	.971	.968	.966	.964	.961
23	.997	.994	.992	.989	.986	.984	.981	.978	.976	.973	.971	.968	.966	.964	.961
24	.997	.994	.992	.989	.986	.984	.981	.978	.976	.973	.971	.968	.966	.964	.961
25	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.974	.972
26	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.974	.972
27	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.974	.972
28	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.974	.972
29	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.974	.972
30	.999	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.972
31	.999	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.972
32	.999	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.972
33	.999	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.972
34	.999	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.972
35	.999	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.972
36	.999	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.972
37	.999	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.972
38	.999	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.972
39	.999	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.972
40	.999	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.972
41	.999	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.972
42	.999	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.972
43	.999	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.972
44	.999	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.972
45	.999	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.972
46	.999	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.972
47	.999	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.972
48	.999	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.972
49	.999	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.972
50	.999	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.972
51	.999	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.972
52	.999	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.972
53	.999	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.972
54	.999	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.972
55	.999	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.972
56	.999	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.972
57	.999	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.972
58	.999	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.972
59	.999	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.972
60	.999	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.972
61	.999	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.972
62	.999	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.972
63	.999	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.972
64	.999	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.972
65	.999	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.972
66	.999	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.972
67	.999	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.972
68	.999	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.972
69	.999	.998	.996	.994	.992	.990	.988	.986	.984	.983	.981	.979	.977	.975	.972
70	1.000	.999	.998	.996	.994	.992	.990	.988	.986	.984	.982	.980	.978	.976	.974
71	1.000	.999	.998	.996	.994	.992	.990	.988	.986	.984	.982	.980	.978	.976	.974
72	1.000	.999	.998	.996	.994	.992	.990	.988	.986	.984	.982	.980	.978	.976	.974
73	1.000	.999	.998	.996	.994	.992	.990	.988	.986	.984	.982	.980	.978	.976	.974
74	1.000	.999	.998	.996	.994	.992	.990	.988	.986	.984	.982	.980	.978	.976	.974
75	1.000	.999	.998	.996	.994	.992	.990	.988	.986	.984	.982	.980	.978	.976	.974
76	1.000	.999	.998	.996	.994	.992	.990	.988	.986	.984	.982	.980	.978	.976	.974
77	1.000	.999	.998	.996	.994	.992	.990	.988	.986	.984	.982	.980	.978	.976	.974
78	1.000	.999	.998	.996	.994	.992	.990	.988	.986	.984	.982	.980	.978	.976	.974
79	1.000	.999	.998	.996	.994	.992	.990	.988	.986	.984	.982	.980	.978	.976	.974
80	1.000	.999	.998	.996	.994	.992	.990	.988	.986	.984	.982	.980	.978	.976	.974
81	1.000	.999	.998	.996	.994	.992	.990	.988	.986	.984	.982	.980	.978	.976	.974
82	1.000	.999	.998	.996	.994	.992	.990	.988	.986	.984	.982	.980	.978	.976	.974
83	1.000	.999	.998	.996	.994	.992	.990	.988	.986	.984	.982	.980	.978	.976	.974
84	1.000	.999	.998	.996	.994	.992	.990	.988	.986	.984	.982	.980	.978	.976	.974
85	1.000	.999	.998	.996	.994	.992	.990	.988	.986	.984	.982	.980	.978	.976	.974
86	1.000	.999	.998	.996	.994	.992	.990	.988	.986	.984	.982	.980	.978	.976	.974
87	1.000	.999	.998	.996	.994	.992	.990	.988	.986	.984	.982	.980	.978	.976	.974
88	1.000	.999	.998	.996	.994	.992	.990	.988	.986	.984	.982	.980	.978	.976	.974
89	1.000	.999	.998	.996	.994	.992	.990	.988	.986	.984	.982	.980	.978	.976	.974
90	1.000	.999	.998	.996	.994	.992	.990	.988	.986	.984	.982	.980	.978	.976	.974
91	1.000	.999	.998	.996	.994	.992	.990	.988	.986	.984	.982	.980	.978	.976	.974
92	1.000	.999	.998	.996	.994	.992	.990	.988	.986	.984	.982	.980	.978	.976	.974
93	1.000	.999	.998	.996	.994	.992	.990	.988	.986	.984	.982	.980	.978	.976	.974
94	1.000	.999	.998	.996	.994	.992	.990	.988	.986	.984	.982	.980	.978	.976	.974
95	1.000	.999	.998</												

- There is no evidence of existing contamination from an on or off-site source.
- There is too few upgradient wells to meaningfully characterize spatial variability (e.g., a site with one upgradient well or a facility in which upgradient water quality is not representative of downgradient water quality).
- The site satisfies specific hydrogeological criteria (e.g., slow moving groundwater zones, no access to upgradient groundwater, inappropriate groundwater migration pathways) as defined by a groundwater professional.

If an intrawell comparison is justified based on meeting one or more of the above criteria, compute intrawell comparisons using combined Shewart-CUSUM control charts [40 CFR 258.53(h)(3)]. In addition, for those wells and constituents that fail upgradient versus downgradient comparisons, compute combined Shewart-CUSUM control charts. If no VOCs or hazardous metals are detected and no trend is detected in other indicator constituents, use intrawell comparisons for detection monitoring of those wells and constituents.

If all background measurements (for either interwell or intrawell comparisons) are nondetects after 13 sampling events, use PQL as statistical decision limit [40 CFR 258.53(h)(5)]. Thirteen samples provides a 99 percent confidence nonparametric prediction limit with one resample [40 CFR 258.53(h)(1) and USEPA 1992 Section 5.2.3].

If detection frequency is greater than zero (i.e., the constituent is detected in at least one background sample) but less than 25 percent, set control limit to the largest of at least 13 background samples.

As an alternative to the two above paragraphs, compute a Poisson prediction limit following collection of eight background samples (USEPA 1992 Section 2.2.4).

#### **4.1.1.3 Verification Resampling**

Verification resampling is an integral part of the statistical methodology (USEPA 1992 Section 5). Without verification resampling, much larger prediction limits would be required to obtain a site-wide false positive rate of 5 percent. The resulting false negative rate would be dramatically increased. Verification resampling allows sequential application of a much smaller prediction limit, therefore minimizing false positive and false

negative rates. A statistically significant exceedance is not declared and should not be reported until the results of the verification resample are known. The probability of an initial exceedance is much higher than 5 percent for the site as a whole.

Requiring passage of two verification resamples (e.g., in the state of California regulation) will lead to higher false negative rates because larger prediction limits are required to achieve a site-wide false positive rate of 5 percent than for a single verification resample. In light of these considerations, one verification resample will be collected in the event of an initial exceedance. Verification resampling will only be performed for the well(s) and constituent(s) that initially exceeded the limit.

#### **4.1.1.4 False Positive and False Negative Rates**

A simulation study will be conducted based on the current monitoring network, constituents, detection frequencies, and distributional form of each monitoring constituent (USEPA 1992 Appendix B). The frequency of verification resamples and false assessments for site as a whole will be projected for each monitoring event based on the results of the simulation study.

#### **4.1.1.5 Use of MDLs and PQLs in Groundwater Monitoring**

The method detection limit (MDL) indicates that the parameter is present in the sample with confidence. For example, an MDL may be constructed with a 99 percent confidence that the analyte is present in the next single sample or 99 percent confidence that the analyte is present in 99 percent of all future detection decisions. It can be concluded that the analyte is present in those samples where the measurement exceeds the MDL. However, exceedance of an MDL provides no quantitative information regarding the true concentration of the constituent in that sample.

The PQL indicates that the true quantitative value of the analyte is close to the measured value (i.e., the minimum quantifiable concentration). Measurements that exceed the PQL are considered quantifiable, therefore the measurements can be used in quantitative analyses such as groundwater monitoring statistical evaluations.

For analytes with estimated concentrations exceeding the MDL but not the PQL, it can only be concluded that the true concentration is greater than zero. There is no way of knowing the actual concentration. For example, if the laboratory-specific MDL for a given compound is 3  $\mu\text{g/L}$ , and the PQL for the same compound is 6  $\mu\text{g/L}$ , then a detection of that compound at 4  $\mu\text{g/L}$  could actually represent a true concentration of anywhere between 0 and 6  $\mu\text{g/L}$ . The true concentration may well be less than the MDL.

Comparison of such a value to a maximum contaminant level (MCL or health-based standard) or any other concentration limit (e.g., alternate concentration limit of ACL) is not meaningful unless the concentration is larger than the PQL. Verification resampling applies to this case as well.

#### **4.1.2 Assessment Monitoring**

The requirements for assessment monitoring were discussed in Section 1.3.2.3. If the facility is placed into assessment monitoring, define background concentrations for any Appendix II compounds detected during background sampling. See Appendix A of this report for a list of Appendix II parameters. Using the interwell or intrawell comparisons described in Section 3.1.1, determine if there is a SSI in one or more of the Appendix II constituents found in the background samples.

#### **4.1.3 Corrective Action Monitoring**

If corrective action is required, use same statistic until background is achieved for 3 years [40 CFR 258.58(e)(2)]. Use Sen's test to evaluate trends (declining) to demonstrate effectiveness of corrective action.

#### **4.1.4 Implementation**

A computer program will be used to implement the detection monitoring plan and will encompass all aspects of the previously presented statistical decision tree. The program will select the appropriate statistical methods based on the decision tree presented in Figure 4-1 at the end of this section.

#### **4.1.5 Case Examples**

The purpose of this section is to provide a description of the specific statistical methods to be used. The following cases are examples of how the decision tree shown in Figure 3-1 can be implemented. Please note, however, that specific recommendations for any given facility require an interdisciplinary site-specific study

that encompasses knowledge of the facility, its hydrogeology, geochemistry, and study of the false positive and false negative error rates that will result.

#### 4.1.5.1 Parametric ANOVA

The steps for evaluating data using a one-way, parametric ANOVA are summarized below:

- Compute the mean concentration,  $Z_i$ , of the parameter in each well
- Compute the overall mean value,  $Z$ , for all results
- Compute the standard deviation,  $\sigma$ , of all results
- Compute the sum of squares,  $SS$ , using the following equations

$$SS_{TOTAL} = (N-1)\sigma^2$$

$$SS_{wells} = \sum_{i=1}^n N_i Z_i^2 - NZ^2$$

$$SS_{ERROR} = SS_{TOTAL} - SS_{WELLS}$$

where  $N$  = total number of samples

$N_i$  = number of samples in each well

- Compute the degrees of freedom,  $DF$ , using the following equations:

$$DF_{WELLS} = \text{Number of Wells} - 1$$

$$DF_{ERROR} = \text{Number of Samples} - \text{Number of Wells}$$

- Divide  $SS_{WELLS}$  by  $DF_{WELLS}$  to produce  $MS_{WELLS}$  and  $SS_{ERROR}$  by  $DF_{ERROR}$  to produce  $MS_{ERROR}$

- Divide  $MS_{WELLS}$  by  $MS_{ERROR}$  to produce the F-ratio
- Compare the F-ratio with the tabulated value based on the appropriate confidence level and degrees of freedom. If the calculate, F-ratio is greater than the tabulated F, an SSI is observed between the background wells and compliance wells.
- If it is determined there is an SSI for a group of wells, perform a post-hoc analysis, as described in the AIFG, using multiple comparisons with a 1 percent false positive rate for each well to determine which well(s) caused the SSI.

#### 4.1.5.2 Nonparametric ANOVA

The steps for evaluating data using the Kruskal-Wallis test (a one-way, nonparametric ANOVA) are summarized below:

- Rank all results from lowest to highest for each parameter. For tied values, the rank assigned is the average rank of the tied values.
- Compute the sum of the ranks for each well.

$$H = \left( \frac{12}{N * (N + 1)} * \sum_{i=1}^k \frac{R_i^2}{N_i} \right) - 3(N + 1)$$

- Compute the H statistic as follows:

where

$R_i$ =	sum of ranks of the ith group
$N$ =	total number of samples
$N_i$ =	number of samples in the ith group

- Adjust H statistic for ties values using the following equations.

$$H' = \frac{H}{1 - \sum_{i=1}^g \frac{T_i}{N^3 - N}}$$

where  $T_i = (t_i^3 - t_i)$   
 $t_i =$  number of tied values in the  $i$ th group of tied values

- Compare  $H'$  to the critical chi-squared value for the appropriate confidence level. If  $H'$  exceeds the chi-squared value, an SSI is observed between the background wells and compliance wells.
- If it is determined there is an SSI for a group of wells, perform a post-hoc analysis, as described in the AIFG, using multiple comparisons with a 1 percent false positive rate for each well to determine which well(s) caused the SSI.

#### 4.1.5.3 Prediction Limit

For those wells and constituents that show similar variability in upgradient and downgradient monitoring zones, interwell comparisons can be performed by computing limits based on historical upgradient data to which individual new downgradient monitoring measurements can be compared. The following text outlines decision rules by which various prediction limits can be computed. The decision points are based on detection frequency and distributional form of the upgradient data.

- Case 1: Compounds quantified in all background samples.
  - Test normality of distribution using the multiple group version of the Shapiro-Wilk test (Wilk and Shapiro, 1968) applied to  $n$  background measurements. The multiple group version of the original Shapiro-Wilk test (Shapiro and Wilk, 1965) takes into consideration that upgradient measurements are nested within different upgradient monitoring wells, hence the original Shapiro-Wilk test does not apply (USEPA, 1992 Section 1.1.4).
  - If normality is not rejected, compute the 95 percent prediction limit as:

$$X + \sqrt{1 + \frac{1}{n} t_{[n-1, \alpha]}^2}$$

where

$$X = \sum_{i=1}^n \frac{X_i}{n}$$

$$S = \sqrt{\sum_{i=1}^n \frac{(X_i - X)^2}{n-1}}$$

where  $\alpha$  is the false positive rate for each individual test,  $t_{[n-1, \alpha]}$  is the one-sided  $(1 - \alpha)$  100 percent point of Student's t distribution on  $n - 1$  degrees of freedom, and  $n$  is the number of background measurements

Select  $\alpha$  as the minimum of .01 or one of the following:

- Pass the first or one of one verification resamples

$$\alpha = (1 - .95^{1/k})^{1/2}$$

- Pass the first or one of two verification resamples

$$\alpha = (1 - .95^{1/k})^{1/3}$$

- Pass the first or two of two verification resamples

$$\alpha = \sqrt{1 - .95^{1/k}} \sqrt{1/2}$$

where k is the number of comparisons (i.e., monitoring wells times constituents (USEPA 1992 Section 5.2.2)).

- If normality is rejected, take natural logarithms of the n background measurements and recompute the multiple group Shapiro-Wilk test.
- If the transformation results in a nonsignificant G statistic (i.e., the values  $\log_e(X)$  are normally distributed - see USEPA 1992 Section 1.1), compute the lognormal prediction limit as:

$$\exp\left(y + \sqrt{1 + \frac{1}{n} t_{(n-1, \alpha)}^2}\right) - 1$$

where

$$y = \sum_{i=1}^n \frac{\log_e(x_i + 1)}{n}$$

and

$$S_y = \sqrt{\frac{\sum_{i=1}^n (\log_e(x_i + 1) - y)^2}{n-1}}$$

- If log transformation does not bring about normality (i.e., the probability of G is less than 0.01), compute nonparametric prediction limits (USEPA 1992 Section 5.2.3) or compute Poisson prediction limit (USEPA 1992 Section 2.2.4.)
- Case 2: Compounds quantified in at least 50 percent of all background samples.
  - Apply the multiple group Shapiro-Wilk test to the  $n_1$  quantified measurements only.
  - If the data are normally distributed compute the mean of the  $n$  background samples as:

$$X = \left(1 - \frac{n_0}{n}\right) x'$$

where  $x'$  is the average of the  $n_1$  detected values, and  $n_0$  is the number of samples in which the compound is not detected or is below the method detection limit. The standard deviation is:

$$s = \sqrt{\left(1 - \frac{n_0}{n}\right) s'^2 + \frac{n_0}{n} \left(1 - \frac{n_0 - 1}{n - 1}\right) x'^2}$$

$$\text{Poisson PL} = y/n + \frac{t^2}{2n} + t/n \sqrt{y(1+n) + t^2/4}$$

where  $y$  is the sum of the detected measurements or reporting limit for those samples in which the constituent was not detected and  $t$  is the  $(1 - \alpha)$  100 upper percentage point of Student's  $t$ -distribution (USEPA 1992 Section 2.2.4)

#### 4.1.5.4 Intrawell Comparisons

One method for computing intrawell comparisons is the combined Shewart-CUSUM control chart (USEPA 1992 Section 6.1). This method is sensitive to both gradual and rapid releases and is useful as a method of detecting "trends" in data. Note that this method should be used on wells unaffected by the landfill. There are several approaches to implementing the method and one way is described below.

The combined Shewart-CUSUM control chart procedure assumes that the data are independent and normally distributed with a fixed mean  $\mu$  and constant variance  $\sigma^2$ . The most important assumption is independence, and as a result, wells should be sampled no more frequently than quarterly. In some cases where groundwater moves relatively quickly, it may be possible to accelerate background sampling to eight samples in a single year. However, this should only be done to establish background and not for routine monitoring. The assumption of normality is somewhat less of a concern, and if problematic, natural log or square root transformation of the observed data should be adequate for most practical applications. For this method, nondetects can be replaced by the method detection limit without serious consequence. This procedure should only be applied to those constituents that are detected at least in 25 percent of all samples, otherwise,  $\sigma^2$  is not adequately defined.

The following guidelines will be used to handle nondetects in the data.

- For those well and constituent combinations in which the detection frequency is less than 25 percent, a graphical display of these data can be provided until a sufficient number of measurements are available to provide 99 percent confidence for an individual well and

constituent using a nonparametric prediction limit. In this context the nonparametric prediction limit is the maximum detected value out of the  $n$  historical measurements. As previously discussed, this amounts to 13 background samples for one resample, eight background samples for pass one of two resamples, and 18 background samples for pass two of two resamples. If nonparametric prediction limits are to be used for intrawell comparisons of rarely detected constituents, two verification resamples will often be required and failure will only be indicated if both measurements exceed the limit (i.e., the maximum of the first eight samples).

- For those cases in which the detection frequency is greater than 25 percent, substitute the median reporting limit for the nondetects so that changes in reporting limits do not appear to be significant trends.
- If nothing is detected in 8, 13, or 18 independent samples (depending on resampling strategy), use the reporting limit as the control limit.
- As in the previously described interwell comparisons, Poisson prediction limits, serving as an alternative to nonparametric prediction limits for rarely detected constituents (i.e., less than 25 percent detected), can be used. Poisson prediction limits can be computed after eight background measurements regardless of detection frequency.

The following procedure will be used to analyze the data:

- At least eight historical independent samples must be available to provide reliable estimates of the mean  $\mu$  and standard deviation  $\sigma$ , of the constituent's concentration in each well.
- Select the three Shewart-CUSUM parameters-  $h$  (the value against which the cumulative sum will be compared),  $k$  (a parameter related to the displacement that should be quickly detected), and SCL (the upper Shewart limit which is the number of standard deviation units for an immediate release). Lucas (1982) and Starks (1988) suggest that  $k = 1$ ,  $h = 5$ , and  $SCL = 4.5$  are most appropriate for groundwater monitoring applications. This is supported

by USEPA in their interim final guidance document Statistical Analysis of Groundwater Monitoring Data at RCRA Facilities (April, 1989) and the Addendum to Interim Final Guidance (USEPA 1992 Section 6.1). For ease of application, select  $h = SCL = 4.5$ , which is slightly more conservative than the value of  $h = 5$  suggested by USEPA. After selection of  $h$ ,  $k$ , and  $SCL$ , perform the following:

- Denote the new measurement at time point  $t_i$  as  $x_i$ .
- Compute the standardized value  $z_i$  using the following equation:

$$z_i = \frac{X_i - \bar{X}}{S}$$

where  $\bar{x}$  and  $s$  are the mean and standard deviation of the at least eight historical measurements for that well and constituent (collected in a period of no less than 1 year).

- At each time period,  $t_i$ , compute the cumulative sum  $S_i$ , as

$$S_i = \max[0, (z_i - K) + S_{i-1}]$$

where  $\max [A, B]$  is the maximum of  $A$  and  $B$ , starting with  $S_0 = 0$ .

- Plot the values of  $S_i$  (y-axis) versus  $t_i$  (x-axis) on a time chart. Declare an "out-of-control" situation on sampling period  $t_i$  if for the first time,  $S_i \geq h$  or  $z_i \geq SCL$ . Any

such designation, however, must be verified on the next round of sampling before further investigation is indicated.

- Note that unlike prediction limits, which provide a fixed confidence level (e.g., 95 percent) for a given number of future comparisons, control charts do not provide explicit confidence levels and do not adjust for the number of future comparisons. The selection of  $h = SCL = 4.5$  and  $k = 1$  is based on USEPA's own review of the literature and simulations (see Lucas, 1982; Starks, 1988; and USEPA, 1989). USEPA indicates that these values "allow a displacement of two standard deviations to be detected quickly." Since 1.96 standard deviation units corresponds to 95 percent confidence on a normal distribution, approximately 95 percent confidence can be achieved for this method as well.
- In terms of plotting the results, it is more intuitive to plot values in their original metric (e.g.,  $\mu\text{g/L}$ ) rather than in standard deviation units. In this case  $h = SCL = \bar{x} + 4.5s$  and the  $S_i$  are converted to the concentration metric by the transformation  $S_i * s + \bar{x}$ , noting that when normalized (i.e., in standard deviation units)  $\bar{x} = 0$  and  $s = 1$  so that  $h = SCL = 4.5$  and  $S_i * 1 + 0 = S_i$ .

From time to time, inconsistently large or small values (outliers) can be observed due to sampling, laboratory, transportation, transcription errors, or even by chance alone. A verification resampling procedure can reduce the probability of concluding that an impact has occurred if such an anomalous value is obtained for any of these reasons. However, nothing has eliminated the chance that such errors might be included in the historical measurements for a particular well and constituent. If such erroneous values (either too high or too low) are included in the historical database, the result would be an artificial increase in the magnitude of the control limit and a corresponding increase in the false negative rate of the statistical test (i.e., conclude that there is no site impact when in fact there is). To remove the possibility of this type of error, historical data are screened for each well and constituent for the existence of outliers (USEPA 1992 Section 6.2) using the Dixon method (Dixon 1953). These outlying data points are indicated on the control charts (using a different symbol), but are excluded from the measurements used to compute the background mean and standard deviation. In the future, new measurements that turn out to be outliers, in that they exceed the control limit,

will be dealt with by verification resampling in downgradient wells only. This same outlier detection algorithm can be applied to each upgradient well and constituent to screen outliers for interwell comparisons.

If contamination is pre-existing, trends will often be observed in the background database from which the mean and variance are computed. This will lead to upward biased estimates and grossly inflated control limits. To remove this possibility, the background data for each well and constituent will be screened for trend using Sen's (1986) nonparametric estimate of trend. Confidence limits for this trend estimate are given by Gilbert (1987). A significant trend is one in which the 99 percent lower confidence bound is greater than zero. In this way, even pre-existing trends in the background dataset will be detected.

During verification resampling it should be noted that when a new monitoring value is an outlier, perhaps due to a transcription error, sampling error, or analytical error, the Shewart and CUSUM portions of the control chart are affected quite differently. The Shewart portion of the control chart compares each individual new measurement to the control limit. Therefore, the next monitoring event measurement constitutes an independent verification of the original result. In contrast, however, the CUSUM procedure incorporates all historical values in the computation. Therefore, the effect of the outlier will be present for both the initial and verification sample. Hence the statistical test will be invalid.

For example, assume  $\bar{x} = 50$ , and  $s = 10$ . During quarter one the new monitoring value is 50, so  $z = (50 - 50)/10 = 0$  and  $S_i = \max[0, (z - 1) + 0] = 0$ . During quarter two, a sampling error occurs and the reported value is 200, yielding  $z = (200 - 50)/10 = 15$  and  $S_i = \max[0, (15 - 1) + 0] = 14$ , which is considerably larger than 4.5. Hence, an initial exceedance is recorded. On the next round of sampling, the previous result is not confirmed because the result is back to 50. Inspection of the CUSUM, however, yields  $z = (50 - 50)/10 = 0$  and  $S_i = \max[0, (0 - 1) + 14] = 13$ , which would be taken as a confirmation of the exceedance, when in fact no such verification was observed. For this reason, the verification must replace the suspected result in order to have an unbiased confirmation.

As monitoring continues and the process is shown to be in control, the background mean and variance will be updated periodically to incorporate new data. Every year or two, all new data that are in control will be pooled with the initial samples and  $\bar{x}$  and  $s$  recomputed. These new values of  $\bar{x}$  and  $s$  will then be used in

constructing future control charts. This updating process should continue for the life of the facility and/or monitoring program (USEPA 1992 Section 6.2).

An alternative approach to intrawell comparisons using control charts involves computation of well-specific prediction limits. Prediction limits are somewhat more sensitive to immediate releases than the combined Shewart-CUSUM control charts. Prediction limits are also less robust to deviations from distributional assumptions. The following text describes the procedures to be used in calculating well-specific prediction limits:

- Compute normal prediction limits as described in the previous section on interwell comparisons.
- For detection frequencies greater than 25 percent, nondetects are replaced with the median reporting limit. For detection frequencies less than 25 percent, either nonparametric or Poisson prediction limits are computed depending on what option the user has selected (i.e., rare-event statistic window).

## **4.2 DESCRIPTION OF STATISTICAL METHODS**

This section gives a brief description of the recommended statistical procedures discussed in Section 4.1.1. More information and detailed examples can be found in the Guidance and AIFG (USEPA, 1989 and 1992).

### **4.2.1 Shapiro-Wilk Test of Normality (for grouped data)**

The Shapiro-Wilk test is a test for normality of a data set (or log-normality if log-transformed data are tested). The ordered values are correlated with the quantiles of a normal distribution to calculate the Shapiro-Wilk statistic  $W$ . This is then compared to tabulated critical values to determine whether there is significant evidence of non-normality. The smaller the value of  $W$ , the less likely that the distribution can be considered normal (Shapiro and Wilk, 1968).

#### 4.2.2 Probability Plotting and the Probability Plot Correlation Coefficient

This is a test for normality of a data set (or log-normality if log-transformed data are tested). Ordered data are plotted against the probabilities for a normal distribution. The plot will be linear for normal data. The significance of any departure from linearity is investigated by calculating the probability plot correlation coefficient and comparing to tabulated critical values.

#### 4.2.3 Detects-Only Probability Plot

This is a probability plot of detected values where only non-detected values are ignored.

#### 4.2.4 Censored Probability Plot

This is a probability plot in which nondetect values are given the lowest ranks and are assigned the corresponding normal probabilities, but are not plotted.

#### 4.2.5 Parametric Prediction Limits

A prediction limit is constructed to contain a specified number of future observations from the same (uncontaminated) well with a specified confidence. If the background data have mean,  $X$ , and standard deviation,  $S$ , the parametric upper prediction limit,  $PL$ , constructed to be greater than  $K$  future samples with confidence  $(1-\beta)$  percent, is:

$$PL = X + KS$$

where  $K$  is calculated as follows:

$$K = t_{n-1, 1-\beta/k} \sqrt{1 + 1/n}$$

where  $n$  is the number of background samples and the  $t$ -value represents the upper  $(1-\beta/k)$ th percentile of the Student's  $t$  distribution with  $(n-1)$  degrees of freedom. If the data are log-normally distributed, all calculations are performed on log-transformed data.

#### 4.2.6 Cohen's Method

This is a method for estimating the mean and standard deviation of a data set containing up to 50 percent nondetect values. Cohen's method assumes that all the data (detects and nondetects) come from the same normal or log-normal population, but that nondetect values have been "censored" at the detection limit; the result of applying the method is a maximum-likelihood estimate of the mean and standard deviation of the full data set. If the data follow a log-normal distribution, Cohen's adjustment is performed on log-transformed data; the resulting estimates of the mean and standard deviation of the log-transformed data can be used for other statistical procedures such as constructing prediction limits.

#### 4.2.7 Aitchison's Method

This is a method for estimating the mean and standard deviation of a data set containing up to 50 percent nondetect values. In contrast to Cohen's method, Aitchison's approach assumes that the nondetect samples are uncontaminated and can be assumed to have zero concentration, thus making it possible to calculate the mean and standard deviation of the data set directly as follows:

$$\mu = \left(1 - \frac{d}{n}\right)x^*$$

$$\sigma^2 = \left(\frac{n-(d+1)}{n-1}\right)(s^*)^2 + \frac{d}{n}\left(\frac{n-d}{n-1}\right)(x^*)^2$$

where  $\mu$  is the estimated mean of the entire data set

$x^*$  is the mean of the detected values

$n$  is the total number of samples

$d$  is the number of nondetects

$\sigma$  is the estimated standard deviation of the entire data set

$s^*$  is the standard deviation of the detected values

#### 4.2.8 Nonparametric Prediction Limits

Nonparametric tolerance and prediction limits are constructed to be independent of any assumed distribution and therefore are suitable for use when the distribution is unknown or can be demonstrated to be neither normal nor lognormal. Nonparametric methods, while generally less powerful than parametric methods for normal data, are frequently more powerful for non-normal data or data containing a large number of nondetect values. The nonparametric prediction limits will be the maximum value in the background set for small data sets, but will be a different value (e.g., the second or third highest) for larger data sets.

#### 4.2.9 Poisson Prediction Limits

This is a method for modeling data with greater than 90 percent nondetects. The detected samples are modeled as "rare events" using the Poisson distribution. The method is described by Gibbons (1987b) and in the AIFG (USEPA 1992). It is based on adding all the concentrations in the background samples for a particular analyte to give the "Poisson count",  $T_n$ , where  $n$  is the number of background samples. Nondetect values are set to one-half the PQL in the Poisson count.

A prediction limit on the Poisson count which includes  $k$  future measurements with confidence  $(1-\beta)$  percent,  $PL_n^k$ , is constructed from the background data as:

$$PL_n^k = \frac{k}{n} T_n + \frac{k}{n} \frac{t^2}{2} + \frac{k}{n} t \sqrt{T_n \left( 1 + \frac{n}{k} \right) + \frac{t^2}{4}}$$

where  $t = t_{n-1, 1-\beta}$  is the upper  $(1-\beta)$ th percentile of the Student's  $t$  distribution with  $(n-1)$  degrees of freedom. This prediction limit is compared to the sum of the concentrations in the sample from a single downgradient well. Nondetected values must be treated identically in calculating downgradient and background Poisson counts.

#### 4.2.10 Shewhart -Cumulative Sum (CUSUM) Control Charts

This is a method for visually comparing changes in concentration in a well with background data from the same well (or sometimes from different wells). Some advantages of control charts are as follows:

- It is a graphical technique and, therefore trends in the data may be more readily apparent than through other comparison techniques.
- Monitoring data is compared to prior data from the same well, thereby removing spatial variability as a confounding factor.

A control chart is a plot of measured concentrations and accumulated concentrations, in standardized units, versus sampling time. Constructing a control chart requires that the baseline data are characteristic of background data (i.e., that the well is initially uncontaminated), background data are normally (or log-normally) distributed, and sufficient detected values are in the baseline data to obtain reliable estimates of the mean and standard deviation. Control charts are probably most appropriate for inorganic parameters that occur naturally at the site.

The following steps involved in using a control chart are as follows:

- Estimate the baseline parameters from the initial sample data (a minimum of four samples over the course of a year, preferably eight). The baseline data are the mean,  $m$ , and standard deviation,  $s$ , of the initial samples.
- Select values for three control parameters:
  - h - A decision interval value generally set to 4 or 5. Five is recommended for groundwater data (Starks, 1988; Lucas, 1982)
  - k - A reference value equal to  $D/2$  where  $D$  is the displacement that should be quickly detected. The EPA recommends selecting  $k=1$ , which will allow a displacement of two standard deviations to be detected quickly.
  - SCL - Shewhart control limit; 4.5 is recommended (Starks, 1988).

- For each time period,  $T_i$ , take  $n_i$  independent samples ( $n_i$  may be one) and calculate the mean,  $x_i$ . Compute the standardized mean  $Z_i$  of the measured concentrations as:

$$Z_i = (x_i - m) \sqrt{n_i} / s$$

Also compute the cumulative sum,  $S_i$ , as:

$$S_i = \max\{0, (Z_i - k) + S_{i-1}\}$$

where  $\max\{A, B\}$  is the maximum of A and B, and  $S_0 = 0$ .

- Plot  $Z_i$  and  $S_i$  against  $T_i$  on the control chart. An "out-of-control" situation (potential contamination) occurs whenever  $Z_i \geq SCL$  or  $S_i \geq h$ . Two different types of situations are controlled by these limits - too large a standardized mean will occur if there is a rapid increase in concentration in the well and too large a cumulative sum may also occur for a more gradual trend.

If the control chart remains "in control" for a long period of time, it is desirable to update the baseline parameters to include more recent observations. This will help to control fluctuations in background values which may occur even in the absence of contamination.

\* \* \* \* \*

## 5.0 SEMIANNUAL GROUNDWATER MONITORING REPORTS

Upon the completion of the semiannual sampling and analysis of the data, a report will be prepared for submission to the Puerto Rico Environmental Quality Board.

Groundwater monitoring reports are required to be submitted to the EQB after each sampling event and placed into the site's operating record. The reports will include the following items:

- Purpose of sampling
- Piezometric surface map
- Copies of field logbooks or Groundwater Sampling Data Sheets
- Chain of custody records
- Copies of raw laboratory analytical results
- Water quality parameters
- Summary of laboratory results
- Laboratory data validation summary
- Results of statistical analysis
- Any deviations from the SAP during the sampling event and reasons for the change
- Certification from a qualified groundwater scientist.

The groundwater flow rate and direction must be determined each time groundwater is sampled. A piezometric surface map that shows groundwater contours and flow direction arrows will be created based on the static water levels taken during each sampling event. This map will be submitted to the EQB along with the report.

The results of the statistical analysis, except during collection of background samples, will be submitted each time groundwater is sampled. The statistical results should include the test(s) performed, any statistical values generated during analysis, and a brief evaluation of the statistical results.

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## **6.0 RESPONSE TO STATISTICAL ANALYSIS AND CORRECTIVE ACTION**

The Environmental Engineering Division of the Public Works Department, U.S. Naval Station Roosevelt Roads, will analyze the results of its groundwater monitoring program on a regular basis. If a statistically significant increase occurs in any detection monitoring parameter is observed, a response to the statistical analysis will be required. In addition, if a contamination plume is identified, it may be necessary to implement corrective action.

### **6.1 RESPONSE TO STATISTICAL ANALYSIS**

A response to the statistical analysis is required under Rule 557 to attempt to isolate the cause of any statistically significant increase in a monitored parameter. The response involves evaluating the existing data, potentially obtaining additional groundwater samples, isolating the source of the statistically significant increase, performing assessment monitoring, and determining a groundwater protection standard.

#### **6.1.1 Response to a Statistically Significant Increase**

The following responses to a statistically significant increase will occur if the subsequent situations are identified:

- If analysis of the upgradient wells shows a statistically significant increase over background levels, USNS Roosevelt Roads will submit the information to the Puerto Rico Environmental Quality Board (EQB).
- If analysis of the downgradient wells shows a statistically significant increase over background levels, USNS Roosevelt Roads will obtain additional samples from the downgradient wells which showed the statistically significant difference and split the samples into two equally sized samples and analyze the samples to determine if the statistically significant increase was caused by a laboratory error.
- If additional samples continue to show the statistically significant increase over background levels, USNS Roosevelt Roads will demonstrate to the EQB within 90 days that the source

of the statistically significant increase is a source other than the sanitary landfill or the statistically significant increase resulted from an error in a sampling, analysis, statistical evaluation or natural variation. If this demonstration cannot be made, USNS Roosevelt Roads will submit a plan to the EQB for a groundwater assessment monitoring program.

### **6.1.2 Assessment Monitoring Program**

An assessment monitoring program will be required if a demonstration cannot be made that a statistically significant increase was caused by a source other than the sanitary landfill or an error occurred. If assessment monitoring is required, a plan will be submitted to the EQB which details the following aspects of the assessment monitoring program:

- Number, location, and depth of existing wells
- Sampling and analytical methods to be used to monitor the parameters listed in Appendix II
- Evaluation procedures, including any use of previously gathered groundwater quality information
- Rate and extent of migration of the contaminant plume in groundwater
- Concentrations of the contaminant plume in groundwater

Sampling and analysis of the groundwater for the Appendix II parameters will occur within 90 days of the beginning of the assessment monitoring program and conducted semiannually thereafter. Each downgradient well will be sampled at least once during the initial sampling event. Each downgradient well with a positive detection of an Appendix II parameter will be sampled during each subsequent semiannual sampling event. If a new parameter is detected during assessment monitoring in the downgradient wells, a minimum of four background samples will be collected and analyzed to establish the background level for the new parameter. USNS Roosevelt Roads will submit the results of the implementation of the assessment monitoring program to EQB.

Upon receipt of the results from each sampling event, the owner or operator will notify the EQB of the parameters detected and place the notification in the operating record. All wells will be sampled semiannually and analyses conducted for all Appendix I parameters and detected Appendix II parameters. The results of the sampling events will be placed in the operating record, and the EQB will be notified of the measured parameter levels. New background concentrations will be established for newly detected parameters during subsequent sampling events, as well as new groundwater protection standards.

If the concentrations of all the Appendix II parameters are at or below background levels for two consecutive sampling events, the owner or operator will reinstate detection monitoring with the approval of EQB. However, if the concentration of any Appendix II parameter is above the background level but below the groundwater protection standard, the owner or operator notify the EQB. The EQB may require the owner or operator to continue assessment monitoring or develop a corrective measures assessment. If one or more Appendix II parameter is detected at a statistically significant level above the groundwater protection standard, the owner or operator will begin the corrective action program. In addition, the owner or operator may install and sample (if needed) additional monitoring wells. The owner or operator will notify all persons who own or occupy land that directly overlies any part of the plume. Continuation of the assessment monitoring program will also occur.

### **6.1.3 Groundwater Protection Standard**

EQB will establish a groundwater protection standard for each detected Appendix II parameter from one of the groundwater protection standards:

- For parameters with a maximum contaminant level (MCL) established under Section 1412 of the Federal Safe Drinking Water Act (40 CFR 141), the standard will be the MCL for that parameter
- For parameters which do not have MCLs under the Federal Safe Drinking Water Act, the standard will be the background for the parameter
- For parameters with background levels higher than the MCL from the Federal Safe Drinking Water Act, the standard will be the background for the parameter

- A level established by the EQB which accounts for relevant factors, including multiple contaminants in the groundwater, exposure threats to sensitive environments, and other site-specific considerations

## **6.2 CORRECTIVE ACTIONS**

Corrective action may be required under Rule 559 to mitigate any potential groundwater contamination. The corrective action requires that an assessment of the appropriate corrective actions be undertaken, an appropriate remedy selected, and the remedy implemented.

Corrective actions may become necessary if any constituents listed in Appendix II are detected at a statistically significant level which exceeds the groundwater protection standards.

### **6.2.1 Assessment of Corrective Measures**

At the request of EQB, the owner or operator will initiate an assessment of the appropriate corrective measures. A report will be prepared within a reasonable time which outlines the corrective measures studied.

The study will involve analyzing (at a minimum) the following items:

- Performance, reliability, ease of implementation, and potential impacts of the potential remedies
- Necessary time to start and complete the potential remedies
- Cost of the potential remedies
- Any permitting or other regulatory requirements associated with the potential remedy

The owner or operator will hold at least one public hearing to allow those interested or affected by the potential remedies to discuss the study's results. The entire assessment phase will be conducted within a reasonable period of time in order to protect the public health.

During the assessment phase, the owner or operator will continue to conduct monitoring, including the assessment monitoring program.

### **6.2.2 Selection of a Remedy**

A corrective measure will be selected after the completion of the assessment phase, which protects the public health, the environment, and groundwater, minimizes the potential for releases, and properly manages all waste materials. Upon the selection of a remedy, the owner or operator will submit a report to the EQB which identifies the proposed remedy within 14 days. The selection report will be placed in the operating record. A timetable which estimates the initiation and completion time periods for the remedy will be included in the selection report.

The EQB will consider the following factors when evaluating the proposed remedy:

- The long- and short-term effectiveness and protectiveness of the proposed remedy and its likelihood of success
- The effectiveness of the proposed remedy to minimize any future releases
- The degree of difficulty involved with implementing the proposed remedy

The EQB will review the proposed timetable using the following factors:

- The extent and nature of the contamination
- The behavior characteristics of the contaminants in groundwater
- The characteristics of the groundwater
- The accuracy of monitoring or modeling techniques

The EQB may not require remediating a release by the owner or operator if it can be demonstrated that the release is from a source other than the sanitary landfill, the aquifer is not a source of drinking water, or the release will not migrate to a body of water where the concentration of the released constituent is above background levels. Additionally, the owner or operator may not need to perform remediation if it can be shown that it is technically impractical or the remediation would have unacceptable cross-media impacts. If

## 7.0 REFERENCES

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## Appendix I Groundwater Monitoring Parameters

USNS Roosevelt Roads Sanitary Landfill  
Ceiba, Puerto Rico

PARAMETER	ANALYTICAL METHOD	PARAMETER	ANALYTICAL METHOD
<b>INORGANIC CONSTITUENTS</b>		<b>ORGANIC CONSTITUENTS (Con't)</b>	
Antimony ✓	SW-846/6010 or SM 3113B	trans-1,4-Dichloro-2-butene ✓	SW-846/8260
Arsenic ✓	SW-846/6010 or SM 3113B	1,1-Dichloroethane ✓	SW-846/8260
Barium ✓	SW-846/6010 or SM 3113D	1,2-Dichloroethane ✓	SW-846/8260
Beryllium ✓	SW-846/6010 or SM 3111B	1,1-Dichloroethylene ✓	SW-846/8260
Cadmium ✓	SW-846/6010 or SM 3111B	cis-1,2-Dichloroethylene ✓	SW-846/8260
Chromium ✓	SW-846/6010 or SM 3111B	trans-1,2-Dichloroethylene ✓	SW-846/8260
Cobalt ✓	SW-846/6010 or SM 3111B	1,2-Dichloropropane ✓	SW-846/8260
Copper ✓	SW-846/6010 or SM 3111B	cis-1,3-Dichloropropene ✓	SW-846/8260
Lead ✓	SW-846/6010 or SM 3111B	trans-1,3-Dichloropropene ✓	SW-846/8260
Nickel ✓	SW-846/6010 or SM 3113B	Ethylbenzene ✓	SW-846/8260
Selenium ✓	SW-846/6010 or SM 3113B	2-Hexanone ✓	SW-846/8260
Silver ✓	SW-846/6010 or SM 3111B	Methyl bromide ✓	SW-846/8260
Thallium ✓ <i>mercury</i>	SW-846/6010 or SM 3113B	Methyl chloride ✓ <i>Dibromide</i>	SW-846/8260
Vanadium ✓	SW-846/6010 or SM 3111B	Methylene bromide ✓	SW-846/8260
Zinc ✓	SW-846/6010 or SM 3111B	Methylene chloride ✓	SW-846/8260
<b>ORGANIC CONSTITUENTS</b>		Methyle ethyl ketone ✓	SW-846/8260
Acetone ✓	SW-846/8260 or EPA 624.2	Methyl iodide ✓ <i>Iodomethane</i>	SW-846/8260
Acrylonitrile ✓	SW-846/8260 or EPA 624.2	4-Methyl-2-pentanone ✓ <i>Methyl</i>	SW-846/8260
Benzene ✓	SW-846/8260 or EPA 624.2	Styrene ✓ <i>Isobutyl Ketone</i>	SW-846/8260
Bromochloromethane ✓	SW-846/8260 or EPA 624.2	1,1,1,2-Tetrachloroethane ✓	SW-846/8260
Bromodichloromethane ✓	SW-846/8260 or EPA 624.2	1,1,2,2-Tetrachloroethane ✓	SW-846/8260
Bromoform ✓	SW-846/8260 or EPA 624.2	Tetrachloroethylene ✓	SW-846/8260
Carbon disulfide ✓	SW-846/8260 or EPA 624.2	Toluene ✓	SW-846/8260
Carbon tetrachloride ✓	SW-846/8260 or EPA 624.2	1,1,1-Trichloroethane ✓	SW-846/8260
Chlorobenzene ✓	SW-846/8260 or EPA 624.2	1,1,2-Trichloroethane ✓	SW-846/8260
Chloroethane ✓	SW-846/8260 or EPA 624.2	Trichloroethylene ✓	SW-846/8260
Chloroform ✓	SW-846/8260 or EPA 624.2	Trichlorofluoromethane ✓	SW-846/8260
Dibromochloromethane ✓	SW-846/8260 or EPA 624.2	1,2,3-Trichloropropane ✓	SW-846/8260
1,2-Dibromo-3-chloropropane ✓	SW-846/8260 or EPA 624.2	Vinyl acetate ✓	SW-846/8260
1,2-Dibromoethane ✓	SW-846/8260 or EPA 624.2	Vinyl chloride ✓	SW-846/8260
<i>1,2-Dibromoethane</i> o-Dichlorobenzene ✓	SW-846/8260 or EPA 624.2	Xylenes ✓	SW-846/8260
<i>1,4-</i> p-Dichlorobenzene ✓	SW-846/8260 or EPA 624.2		

Note: Alternate EPA SW-846 methods may be used assuming that there is no increase in detection limits.

**APPENDIX B**  
**SAMPLE DOCUMENTATION**



### EXAMPLE SAMPLE LABEL

ROUTE TO	Burns & McDonnell WCI	ANALYSIS
	9400 Ward Parkway	
	Kansas City, MO 64114	
	Phone: (816) 333-8787	
Sample Group: _____		
Sample Point: _____		
Sample Designator: _____		
Sample Round: _____ Year: _____		
Sample Depth From: _____ To: _____		
Date Sampled: _____		
Time Sampled: _____		
Preservation: _____		

### EXAMPLE CUSTODY SEAL

Burns & McDonnell WCI	Signature _____
9400 Ward Parkway	
Kansas City, MO	Date _____

**APPENDIX C**  
**LABORATORY QUALITY ASSURANCE PLAN**

Common name <sup>2</sup>	CAS RN <sup>3</sup>	Common name <sup>2</sup>	CAS RN <sup>3</sup>	Common name <sup>2</sup>	CAS RN <sup>3</sup>
(37) trans-1,2-Dichloroethylene; trans-1,2-Dichloroethene	156-60-5	(47) Methyl ethyl ketone; MEK; 2-Butanone	78-83-3	(59) 1,2,3-Trichloropropane	96-18-4
(38) 1,2-Dichloropropane; Propylene dichloride	78-87-5	(48) Methyl iodide; Iodomethane	74-88-4	(60) Vinyl acetate	108-05-4
(39) cis-1,3-Dichloropropene	10061-01-5	(49) 4-Methyl-2-pentanone; Methyl isobutyl ketone	108-10-1	(61) Vinyl chloride	75-01-4
(40) trans-1,3-Dichloropropene	10061-02-6	(50) Styrene	100-42-5	(62) Xylenes	1330-20-7
(41) Ethylbenzene	100-41-4	(51) 1,1,1,2-Tetrachloroethane	630-20-6		
(42) 2-Hexanone; Methyl butyl ketone	591-78-6	(52) 1,1,2,2-Tetrachloroethane	79-34-5		
(43) Methyl bromide; Bromomethane	74-83-9	(53) Tetrachloroethylene; Tetrachloroethene; Perchloroethylene	127-18-4		
(44) Methyl chloride; Chloromethane	74-87-3	(54) Toluene	108-88-3		
(45) Methylene bromide; Dibromomethane	74-95-3	(55) 1,1,1-Trichloroethane; Methylchloroform	71-55-6		
(46) Methylene chloride; Dichloromethane	75-09-2	(56) 1,1,2-Trichloroethane	79-00-5		
		(57) Trichloroethylene; Trichloroethene	79-01-6		
		(58) Trichlorofluoromethane; CFC-11	75-89-4		

<sup>1</sup> This list contains 47 volatile organics for which possible analytical procedures provided in EPA Report SW-846 "Test Methods for Evaluating Solid Waste," third edition, November 1986, as revised December 1987, includes Method 8260; and 15 metals for which SW-846 provides either Method 6010 or a method from the 7000 series of methods.

<sup>2</sup> Common names are those widely used in government regulations, scientific publications, and commerce; synonyms exist for many chemicals.

<sup>3</sup> Chemical Abstracts Service registry number. Where "Total" is entered, all species in the ground water that contain this element are included.

Appendix II to this Part 258—List of Hazardous Inorganic and Organic Constituents <sup>1</sup>

Common Name <sup>2</sup>	CAS RN <sup>3</sup>	Chemical abstracts service index name <sup>4</sup>	Suggested methods <sup>5</sup>	PCL (µg/L) <sup>6</sup>
Acenaphthene	83-32-9	Acenaphthylene, 1,2-dihydro	8100 8270	200 10
Acenaphthylene	208-96-8	Acenaphthylene	8100 8270	200 10
Acetone	67-64-1	2-Propanone	8260	100
Acetonitrile; Methyl cyanide	75-05-8	Acetonitrile	8015	100
Acetophenone	98-86-2	Ethanone, 1-phenyl	8270	10
2-Acetylaminofluorene; 2-AAF	53-86-3	Acetamide, N-9H-fluoren-2-yl	8270	20
Acrolein	107-02-8	2-Propenal	8030 8260	5 100
Acrylonitrile	107-13-1	2-Propenenitrile	8030 8260	5 200
Aldrin	309-00-2	1,4,5,8-Dimethanonaphthalene, 1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro- (1α,4α,4aβ,5α,8α,8aβ)-	8080	0.05
Allyl chloride	107-05-1	1-Propene, 3-chloro	8270 8010 8260	10 5 10
4-Aminobiphenyl	92-67-1	[1,1'-Biphenyl]-4-amine	8270	20
Anthracene	120-12-7	Anthracene	8100 8270	200 10
Antimony	(Total)	Antimony	8010 7040 7041	300 2000 30
Arsenic	(Total)	Arsenic	8010 7060 7061	500 10 20
Barium	(Total)	Barium	8010 7080	20 1000
Benzene	71-43-2	Benzene	8020 8021 8260	2 0.1 5
Benzo[a]anthracene; Benzanthracene	56-55-3	Benz[a]anthracene	8100 8270	200 10
Benzo[b]fluoranthene	205-89-2	Benz[e]acephenanthrylene	8100 8270	200 10
Benzo[k]fluoranthene	207-08-9	Benzo[k]fluoranthene	8100 8270	200 10
Benzo[ghi]perylene	191-24-2	Benzo[ghi]perylene	8100 8270	200 10
Benzo[a]pyrene	50-32-8	Benzo[a]pyrene	8100 8270	200 10
Benzyl alcohol	100-51-6	Benzenemethanol	8270	20
Beryllium	(Total)	Beryllium	8010 7080 7091	3 50 2
alpha-BHC	319-84-6	Cyclohexane, 1,2,3,4,5,6-hexachloro-, (1α,2α,3β,4α,5β,6β)-	8080 8270	0.05 10
beta-BHC	319-85-7	Cyclohexane, 1,2,3,4,5,6-hexachloro-, (1α,2β,3α,4β,5α,6β)-	8080 8270	0.05 20
delta-BHC	319-86-8	Cyclohexane, 1,2,3,4,5,6-hexachloro-, (1α,2α,3α,4β,5α,6β)-	8080 8270	0.1 20

Common Name <sup>1</sup>	CAS RN <sup>2</sup>	Chemical abstracts service index name <sup>4</sup>	Sug- gested meth- ods <sup>3</sup>	POL ( $\mu$ g/ L) <sup>5</sup>
gamma-BHC; Lindane	58-89-9	Cyclohexane, 1,2,3,4,5,6-hexachloro-, (1 $\alpha$ ,2 $\alpha$ ,3 $\beta$ ,4 $\alpha$ ,5 $\alpha$ ,6 $\beta$ )	8080 8270	0.05 20
Bis(2-chloroethoxy)methane	111-91-1	Ethane, 1,1'-[methylenebis(oxy)]bis[2-chloro-	8110 8270	5 10
Bis(2-chloroethyl) ether; Dichloroethyl ether	111-44-4	Ethane, 1,1'-oxybis[2-chloro-	8110 8270	3 10
Bis-(2-chloro-1-methylethyl) ether; 2,2'-Dichlorodisopropyl ether; DCIP. See note 7	108-60-1	Propane, 2,2'-oxybis[1-chloro-	8110 8270	10 10
Bis(2-ethylhexyl) phthalate	117-81-7	1,2-Benzenedicarboxylic acid, bis(2-ethylhexyl) ester	8060	20
Bromochloromethane; Chlorobromomethane	74-97-5	Methane, bromochloro-	8021 8260	0.1 5
Bromodichloromethane; Dibromochloromethane	75-27-4	Methane, bromodichloro-	8010 8021 8260	1 0.2 5
Bromoform; Tribromomethane	75-25-2	Methane, tribromo-	8010 8021 8260	2 15 5
4-Bromophenyl phenyl ether	101-55-3	Benzene, 1-bromo-4-phenoxy-	8110 8270	25 10
Butyl benzyl phthalate; Benzyl butyl phthalate	85-68-7	1,2-Benzenedicarboxylic acid, butyl phenylmethyl ester	8060 8270	5 10
Cadmium	(Total)	Cadmium	6010 7130 7131	40 50 1
Carbon disulfide	75-15-0	Carbon disulfide	8260	100
Carbon tetrachloride	56-23-5	Methane, tetrachloro-	8010 8021 8260	1 0.1 10
Chlordane	See Note 8	4,7-Methano-1H-indene, 1,2,4,5,6,7,8,8-octachloro-2,3,3a,4,7,7a-hexahydro-	8080 8270	0.1 50
p-Chloroaniline	106-47-8	Benzenamine, 4-chloro-	8270	20
Chlorobenzene	108-90-7	Benzene, chloro-	8010 8020 8021 8260	2 2 0.1 5
Chlorobenzilate	510-15-6	Benzeneacetic acid, 4-chloro- $\alpha$ -(4-chlorophenyl)- $\alpha$ -hydroxy-ethyl ester	8270	10
p-Chloro-m-cresol; 4-Chloro-3-methylphenol	59-50-7	Phenol, 4-chloro-3-methyl-	8040 8270	5 20
Chloroethane; Ethyl chloride	75-00-3	Ethane, chloro-	8010 8021 8260	5 1 10
Chloroform; Trichloromethane	67-66-3	Methane, trichloro-	8010 8021 8260	0.5 0.2 5
2-Chloronaphthalene	91-58-7	Naphthalene, 2-chloro-	8120 8270	10 10
2-Chlorophenol	95-57-8	Phenol, 2-chloro-	8040 8270	5 10
4-Chlorophenyl phenyl ether	7005-72-3	Benzene, 1-chloro-4-phenoxy-	8110 8270	40 10
Chloroprene	126-99-8	1,3-Butadiene, 2-chloro-	8010 8260	50 20
Chromium	(Total)	Chromium	6010 7190 7191	70 500 10
Chrysene	218-01-9	Chrysene	8100 8270	200 10
Cobalt	(Total)	Cobalt	6010 7200 7201	70 500 10
Copper	(Total)	Copper	6010 7210 7211	60 200 10
m-Cresol; 3-methylphenol	108-39-4	Phenol, 3-methyl-	8270	10
o-Cresol; 2-methylphenol	95-48-7	Phenol, 2-methyl-	8270	10
p-Cresol; 4-methylphenol	106-44-5	Phenol, 4-methyl-	8270	10
Cyanide	57-12-5	Cyanide	9010	200
2,4-D; 2,4-Dichlorophenoxyacetic acid	94-75-7	Acetic acid, (2,4-dichlorophenoxy)-	8150	10
4,4'-DDD	72-54-8	Benzene 1,1'-(2,2-dichloroethylidene)bis[4-chloro-	8080 8270	0.1 10
4,4'-DDE	72-55-9	Benzene, 1,1'-(dichloroethylidene)bis[4-chloro-	8080 8270	0.05 10
4,4'-DDT	50-29-3	Benzene, 1,1'-(2,2,2-trichloroethylidene)bis[4-chloro-	8080 8270	0.1 10
Diallate	2303-16-4	Carbamothioic acid, bis(1-methylethyl)-,S-(2,3-dichloro-2-propenyl) ester	8270	10

Common Name <sup>a</sup>	CAS RN <sup>b</sup>	Chemical abstracts service index name <sup>c</sup>	Sug- gested meth- ods <sup>d</sup>	PCL (µg/ L) <sup>e</sup>
Dibenz[a,h]anthracene.....	53-70-3	Dibenz[a,h]anthracene.....	8100 8270	200 10
Dibenzofuran.....	132-64-9	Dibenzofuran.....	8270	10
Dibromochloromethane; Chlorodibromomethane.....	124-48-1	Methane, dibromochloro.....	8010 8021 8260	1 0.3 5
1,2-Dibromo-3-chloropropane; DBCP.....	96-12-8	Propene, 1,2-dibromo-3-chloro.....	8011 8021 8260	0.1 30 25
1,2-Dibromoethane; Ethylene dibromide; EDB.....	106-93-4	Ethane, 1,2-dibromo.....	8011 8021 8260	0.1 10 5
Di-n-butyl phthalate.....	84-74-2	1,2-Benzenedicarboxylic acid, dibutyl ester.....	8060 8270	5 10
o-Dichlorobenzene; 1,2-Dichlorobenzene.....	95-50-1	Benzene, 1,2-dichloro.....	8010 8020 8021 8120 8260 8270	2 5 0.5 10 5 10
m-Dichlorobenzene; 1,3-Dichlorobenzene.....	541-73-1	Benzene, 1,3-Dichloro.....	8010 8020 8021 8120 8260 8270	5 5 0.2 10 5 10
p-Dichlorobenzene; 1,4-Dichlorobenzene.....	106-48-7	Benzene, 1,4-dichloro.....	8010 8020 8021 8120 8260 8270	2 5 0.1 15 5 10
3,3'-Dichlorobenzidine.....	91-04-1	[1,1'-Biphenyl]-4,4'-diamine, 3,3'-dichloro.....	8270	20
trans-1,4-Dichloro-2-butene.....	110-57-6	2-Butene, 1,4-dichloro-, (E).....	8260	100
Dichlorodifluoromethane; CFC 12.....	75-71-8	Methane, dichlorodifluoro.....	8021 8260	0.5 5
1,1-Dichloroethane; Ethylidene chloride.....	75-34-3	Ethane, 1,1-dichloro.....	8010 8021 8260	1 0.5 5
1,2-Dichloroethane; Ethylene dichloride.....	107-06-2	Ethane, 1,1-dichloro.....	8010 8021 8260	0.5 0.3 5
1,1-Dichloroethylene; 1,1-Dichloroethene; Vinylidene chloride.....	75-35-4	Ethene, 1,1-dichloro.....	8010 8021 8260	1 0.5 5
cis-1,2-Dichloroethylene; cis-1,2-Dichloroethene.....	158-59-2	Ethene, 1,2-dichloro-, (Z).....	8021 8260	0.2 5
trans-1,2-Dichloroethylene; trans-1,2-Dichloroethene.....	156-80-5	Ethene, 1,2-dichloro-, (E).....	8010 8021 8260	1 0.5 5
2,4-Dichlorophenol.....	120-83-2	Phenol, 2,4-dichloro.....	8040 8270	5 10
2,6-Dichlorophenol.....	87-85-0	Phenol, 2,6-dichloro.....	8270	10
1,2-Dichloropropane; Propylene dichloride.....	78-87-5	Propene, 1,2-dichloro.....	8010 8021 8260	0.5 0.05 5
1,3-Dichloropropane; Trimethylene dichloride.....	142-28-9	Propene, 1,3-dichloro.....	8021 8260	0.3 5
2,2-Dichloropropane; Isopropylidene chloride.....	594-20-7	Propene, 2,2-dichloro.....	8021 8260	0.5 15
1,1-Dichloropropene.....	563-58-6	1-Propene, 1,1-dichloro.....	8021 8260	0.2 5
cis-1,3-Dichloropropene.....	10061-01-5	1-Propene, 1,3-dichloro-, (Z).....	8010 8260	20 10
trans-1,3-Dichloropropene.....	10061-02-6	1-Propene, 1,3-dichloro-, (E).....	8010 8260	5 10
Dieldrin.....	60-57-1	2,7,3,6-Dimethanonaphth[2,3-b]oxirene, 3,4,5,6,8,9-hexa- chloro-1a,2,2a,3,6,6a,7,7a-octahydro-, (1a,2β,2aa,3β, 6β,6aa,7β,7aa).....	8080 8270	0.05 10
Diethyl phthalate.....	84-66-2	1,2-Benzenedicarboxylic acid, diethyl ester.....	8060 8270	5 10
0,0-Diethyl 0-2-pyrazinyl phosphorothioate; Thionazin.....	297-97-2	Phosphorothioic acid, 0,0-diethyl 0-pyrazinyl ester.....	8141 8270	5 20
Dimethoate.....	60-51-5	Phosphorodithioic acid, 0,0-dimethyl S-[2-(methylamino)-2- oxyethyl] ester.....	8141 8270	3 20
p-(Dimethylamino)azobenzene.....	80-11-7	Benzenamine, N,N-dimethyl-4-(phenylazo).....	8270	10
7,12-Dimethylbenz[a]anthracene.....	57-97-8	Benz[a]anthracene, 7,12-dimethyl.....	8270	10

—Continued

Common Name <sup>a</sup>	CAS RN <sup>a</sup>	Chemical abstracts service index name <sup>a</sup>	Sug- gested meth- ods <sup>a</sup>	PCL (µg/ L) <sup>a</sup>
Lead.....	(Total)	Lead.....	8010 7420 7421	400 1000 10
Mercury.....	(Total)	Mercury.....	7470	2
Methacrylonitrile.....	126-98-7	2-Propenenitrile, 2-methyl.....	8015	5
Methacrylonitrile.....	91-80-5	1,2-Ethanediamine, N,N-dimethyl-N <sup>1</sup> -2-pyridinyl-N <sup>1</sup> /2-thienyl-methyl.....	8260 8270	100 100
Methoxychlor.....	72-43-5	Benzene, 1,1'-(2,2,2-trichloroethylidene)bis[4-methoxy-.....	8080 8270	2 10
Methyl bromide; Bromomethane.....	74-83-9	Methane, bromo.....	8010 8021	20 10
Methyl chloride; Chloromethane.....	74-87-3	Methane, chloro.....	8010 8021	1 0.3
3-Methylcholanthrene.....	56-49-5	Benz[ <i>a</i> ]aceanthrylene, 1,2-dihydro-3-methyl.....	8270	10
Methyl ethyl ketone; MEK; 2-Butanone.....	78-93-3	2-Butanone.....	8015 8260	10 100
Methyl iodide; Iodomethane.....	74-88-4	Methane, iodo.....	8010 8260	40 10
Methyl methacrylate.....	80-62-6	2-Propenoic acid, 2-methyl-, methyl ester.....	8015 8260	2 30
Methyl methanesulfonate.....	66-27-3	Methanesulfonic acid, methyl ester.....	8270	10
2-Methylnaphthalene.....	91-57-6	Naphthalene, 2-methyl.....	8270	10
Methyl parathion; Parathion methyl.....	298-00-0	Phosphorothioic acid, O,O-dimethyl O-(4-nitrophenyl) ester.....	8140 8141 8270	0.5 1 10
4-Methyl-2-pentanone; Methyl isobutyl ketone.....	106-10-1	2-Pentanone, 4-methyl.....	8015 8260	5 100
Methylene bromide; Dibromomethane.....	74-85-3	Methane, dibromo.....	8010 8021	15 20
Methylene chloride; Dichloromethane.....	75-09-2	Methane, dichloro.....	8260 8010 8021	10 5 0.2
Naphthalene.....	91-20-3	Naphthalene.....	8260 8021 8100 8270	10 0.5 200 5
1,4-Naphthoquinone.....	130-15-4	1,4-Naphthalenedione.....	8270	10
1-Naphthylamine.....	134-32-7	1-Naphthalenamine.....	8270	10
2-Naphthylamine.....	91-59-8	2-Naphthalenamine.....	8270	10
Nickel.....	(Total)	Nickel.....	6010 7520	150 400
o-Nitroaniline; 2-Nitroaniline.....	88-74-4	Benzenamine, 2-nitro.....	8270	50
m-Nitroaniline; 3-Nitroaniline.....	99-09-2	Benzenamine, 3-nitro.....	8270	50
p-Nitroaniline; 4-Nitroaniline.....	100-01-6	Benzenamine, 4-nitro.....	8270	20
Nitrobenzene.....	98-95-3	Benzene, nitro.....	8090 8270	40 10
o-Nitrophenol; 2-Nitrophenol.....	88-75-5	Phenol, 2-nitro.....	8040 8270	5 10
p-Nitrophenol; 4-Nitrophenol.....	100-02-7	Phenol, 4-nitro.....	8040 8270	10 50
N-Nitrosodi-n-butylamine.....	924-16-3	1-Butanamine, N-butyl-N-nitroso.....	8270	10
N-Nitrosodiethylamine.....	55-18-5	Ethanamine, N-ethyl-N-nitroso.....	8270	20
N-Nitrosodimethylamine.....	62-75-9	Methanamine, N-methyl-N-nitroso.....	8070	2
N-Nitrosodiphenylamine.....	86-30-6	Benzenamine, N-nitroso-N-phenyl.....	8070	5
N-Nitrosodipropylamine; N-Nitroso-N-dipropylamine; Di-n-propylnitrosamine.....	621-64-7	1-Propanamine, N-nitroso-N-propyl.....	8070	10
N-Nitrosomethylethylamine.....	10595-95-6	Ethanamine, N-methyl-N-nitroso.....	8270	10
N-Nitrosopiperidine.....	100-75-4	Piperidine, 1-nitroso.....	8270	20
N-Nitrosopyrrolidine.....	930-55-2	Pyrrolidine, 1-nitroso.....	8270	40
5-Nitro-o-toluidine.....	99-55-8	Benzenamine, 2-methyl-5-nitro.....	8270	10
Parathion.....	56-38-2	Phosphorothioic acid, O,O-diethyl O-(4-nitrophenyl) ester.....	8141 8270	0.5 10
Pentachlorobenzene.....	608-93-5	Benzene, pentachloro.....	8270	10
Pentachloronitrobenzene.....	82-68-8	Benzene, pentachloronitro.....	8270	20
Pentachlorophenol.....	87-86-5	Phenol, pentachloro.....	8040 8270	5 50
Phenacetin.....	62-44-2	Acetamide, N-(4-ethoxyphenyl).....	8270	20
Phenanthrene.....	85-01-8	Phenanthrene.....	8100 8270	200 10
Phenol.....	108-95-2	Phenol.....	8040	1
p-Phenylenediamine.....	106-50-3	1,4-Benzenediamine.....	8270	10
Phorate.....	298-02-2	Phosphorodithioic acid, O,O-diethyl S-[(ethythio)methyl] ester.....	8140 8141 8270	2 0.5 1

-Continued

Common Name <sup>1</sup>	CAS RN <sup>2</sup>	Chemical abstracts service index name <sup>4</sup>	Sug- gested meth- ods <sup>3</sup>	PCL (µg/ L) <sup>4</sup>
Polychlorinated biphenyls; PCBs; Aroclors	Seg Note 9	1,1'-Biphenyl, chloro derivatives	8080 8270	50 200
Pronamide	23950-58-5	Benzamide, 3,5-dichloro-N-(1,1-dimethyl-2-propenyl)-	8270	10
Propionitrile; Ethyl cyanide	107-12-0	Propanenitrile	8015 8260	60 150
Pyrene	129-00-0	Pyrene	8100 8270	200 10
Safrole	94-59-7	1,3-Benzodioxole, 5-(2-propenyl)-	8270	10
Selenium	(Total)	Selenium	6010 7740 7741	750 20 20
Silver	(Total)	Silver	6010 7760 7761	70 100 10
Silver; 2,4,5-TP	93-72-1	Propanoic acid, 2-(2,4,5-trichlorophenoxy)-	8150	2
Styrene	100-42-5	Benzene, ethenyl-	8020 8021 8260	1 0.1 10
Sulfide	18496-25-8	Sulfide	9030	4000
2,4,5-T; 2,4,5-Trichlorophenoxyacetic acid	93-76-6	Acetic acid, (2,4,5-trichlorophenoxy)-	8150	2
1,2,4,5-Tetrachlorobenzene	95-94-3	Benzene, 1,2,4,5-tetrachloro-	8270	10
1,1,1,2-Tetrachloroethane	630-20-8	Ethane, 1,1,1,2-tetrachloro-	8010 8021 8260	5 0.05 5
1,1,2,2-Tetrachloroethane	79-34-5	Ethane, 1,1,2,2-tetrachloro-	8010 8021 8260	0.5 0.1 5
Tetrachloroethylene; Tetrachloroethene; Perchloroethylene	127-18-4	Ethene, tetrachloro-	8010 8021 8260	0.5 0.5 5
2,3,4,6-Tetrachlorophenol	58-90-2	Phenol, 2,3,4,6-tetrachloro-	8270	10
Thallium	(Total)	Thallium	6010 7840 7841	400 1000 10
Tin	(Total)	Tin	6010	40
Toluene	108-88-3	Benzene, methyl-	8020 8021 8260	2 0.1 5
o-Toluidine	95-53-4	Benzenamine, 2-methyl-	8270	10
Toxaphene	See Note 10	Toxaphene	8080	2
1,2,4-Trichlorobenzene	120-82-1	Benzene, 1,2,4-trichloro-	8021 8120 8260	0.3 0.5 10
1,1,1-Trichloroethane; Methylchloroform	71-55-6	Ethane, 1,1,1-trichloro-	8270 8010 8021 8260	10 0.3 0.3 5
1,1,2-Trichloroethane	79-00-5	Ethane, 1,1,2-trichloro-	8010 8260	0.2 5
Trichloroethylene; Trichloroethene	79-01-6	Ethene, trichloro-	8010 8021 8260	1 0.2 5
Trichlorofluoromethane; CFC-11	75-69-4	Methane, trichlorofluoro-	8010 8021 8260	10 0.3 5
2,4,5-Trichlorophenol	95-95-4	Phenol, 2,4,5-trichloro-	8270	10
2,4,6-Trichlorophenol	88-06-2	Phenol, 2,4,6-trichloro-	8040 8270	5 10
1,2,3-Trichloropropane	96-18-4	Propane, 1,2,3-trichloro-	8010 8021 8260	10 5 15
0,0,0-Triethyl phosphorothioate	126-68-1	Phosphorothioic acid, 0,0,0-triethylester	8270	10
sym-Trinitrobenzene	99-35-4	Benzene, 1,3,5-trinitro-	8270	10
Vanadium	(Total)	Vanadium	6010 7910 7911	5 2000 40
Vinyl acetate	108-05-4	Acetic acid, ethenyl ester	8260	50
Vinyl chloride; Chloroethene	75-01-4	Ethene, chloro-	8010 8021 8260	2 0.4 10
Xylene (total)	See Note 11	Benzene, dimethyl-	8020 8021 8260	5 0.2 5
Zinc	(Total)	Zinc	6010 7950 7951	20 50 0.5